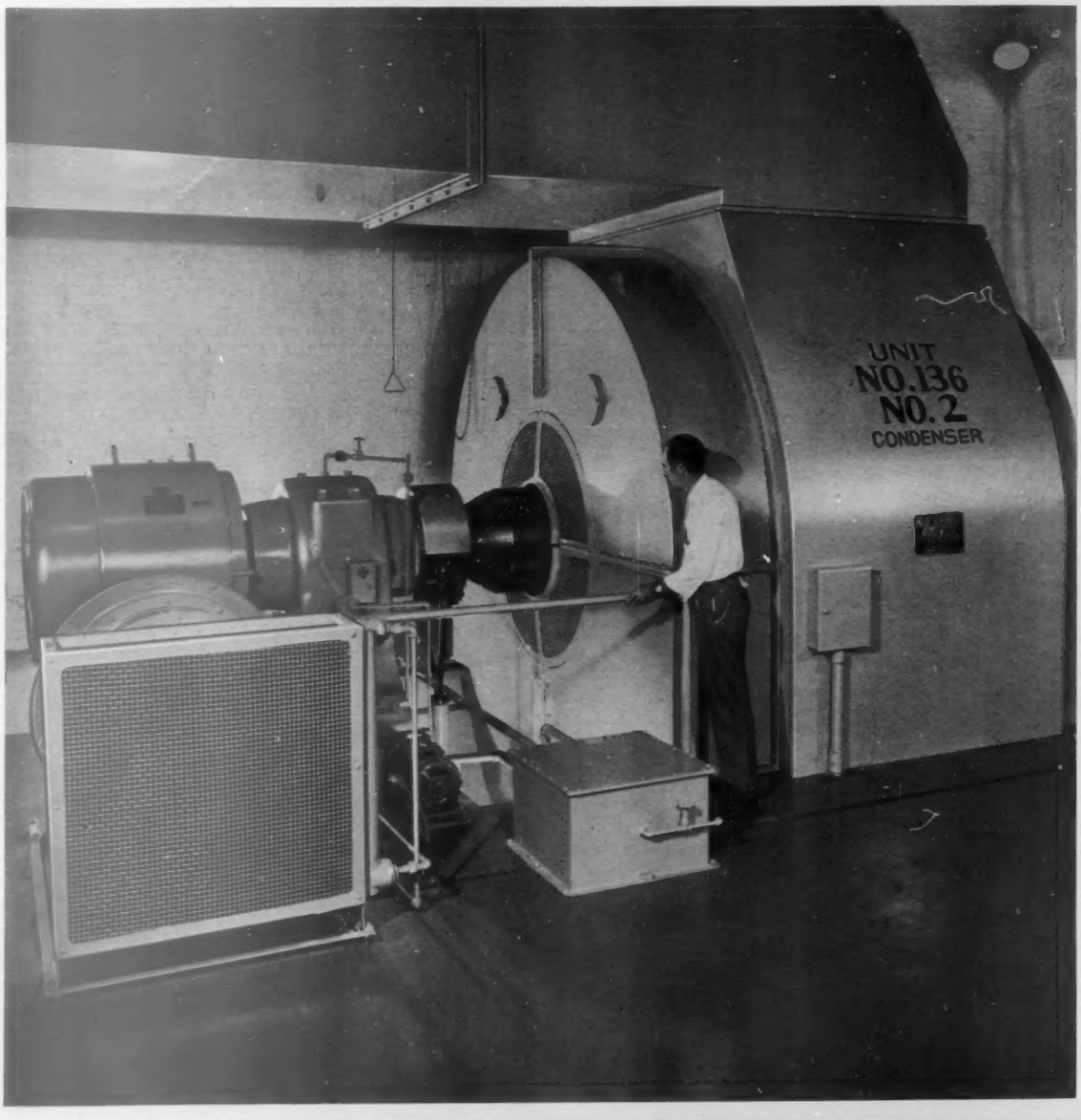
ALLIS-CHALMERS

Electrical Review



Third Quarter, 1947

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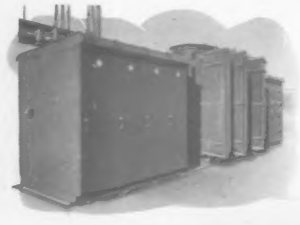

MCS

Allis-Chalmers multi-circuit unit substation. Consists of two or more vertical lift metal-clad switchgear units, throat-connected to 1 or 2 transformers.

SCS

Allis-Chalmers single-circuit unit substation consists of transformer, secondary breaker and control, combined within single housing. Install as a unit.

ALLIS-CHALMERS

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ONE OF TWO 20,000 kva synchronous condensers used in a large steel plant in Ohio to raise power factor and reduce power cost. This 6,900-volt, 720 rpm unit is self-ventilating. Electronically filtered air is taken from the condenser room, circulated through the unit and discharged through the overhead duct. Bearings are force-lubricated with air-cooled oil. Equipment includes a 100 kw main and a 3½ kw pilot exciter, oil circulating pumps, and high pressure oil pumps for starting.

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ALLIS-CHALMERS Electrical REVIEW

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100 YEARS 1847-1947

Allis-Chalmers Mfg. Co.

JUST 100 YEARS AGO, in 1847, two young men fresh from Ohio, Decker and Seville by name, opened a small shop at what is now downtown Milwaukee, for finishing French burr millstones for the rapidly expanding flour and cereal milling business in the upper Great Lakes area. Both the business and their range of products expanded swiftly. By 1861, when the company became Edward P. Allis and Co., it was the largest iron works in Milwaukee, shipping "millstones, hoisting screws, lighter screws, damsons, mill ricks, proof staffs, etc.," all over the midwest and even around Cape Horn to California. Under the leadership of Edward P. Allis, the company became known all over the world for outstanding sawmill, flour milling, and pumping machinery and for Reynolds-Corliss and Allis-triple expansion steam engines.

Through a series of expansions and mergers the company has become the Allis-Chalmers Mfg. Co. of today, maker of the world's widest range of industrial equipment and a leading producer of agricultural tractors and machinery.

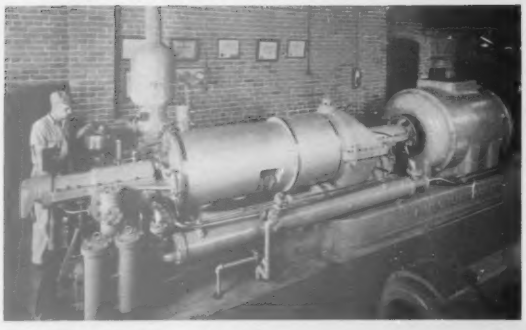
BUILT INTO the lathe headstock, this motor operating from a multiple voltage system was one of the very first integral machine tool drives back in 1894. The Bullock Co. led the world in the development of machine tool, printing press, and other drives utilizing the multiple voltage system for speed control with balancing sets, their own development.

ABOUT 1900 this 400 hp wound rotor induction motor for pumping service in Canada was one of the world's largest. Construction of a 400 hp unit then seemed to be simply an enlarged version of a smaller rating.

IN 1884, two years after Edison's famous Pearl Street Station began to generate power, the George F. Card Co. started to build electric street car brakes at Second and Plum Streets in Cincinnati. They soon began the manufacture of small motors to operate on an arc lamp circuit, the only power in Cincinnati at that time. The manufacture of motors and dynamos in constantly increasing sizes was then continuous through a number of organizational changes. Later known as the Bullock Electric Manufacturing Co., the Cincinnati firm eventually became part of the Allis-Chalmers Mfg. Co., retaining its present location at Norwood, a Cincinnati suburb. The plant, greatly expanded, is now devoted to the manufacture of smaller motors and pumps.

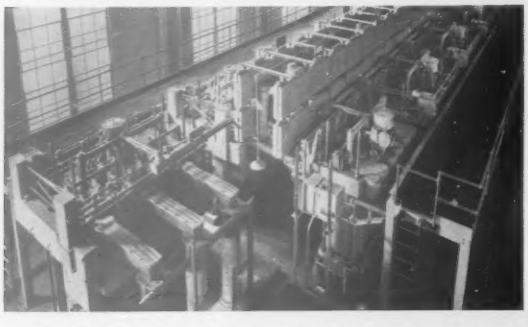
The earliest Card motor of which a photograph is available is the old type "A" constant potential dynamo shown above—about 15 hp, built in 1891. Insulating live machine from ground with a wood base was considered good engineering practice and much safer than trusting the winding insulation.

IN 1902 the company built the 3125 kw 60 cycle 4000 volt 75 rpm generator shown at right for the Cincinnati Gas and Electric Co. The rotor was 30 feet in diameter, big even by today's standards. While Bullock furnished both this alternator and a 2500 kw, 250 volt d-c generator for the same plant, Allis-Chalmers, by then the world's leading builder of the cross-compound steam engine, furnished the driving engines. Two years later the obvious need for complete engineering coordination between the builders of the prime mover and the generators led the Allis-Chalmers Co., already known for steam and gas engines, flour, sawmill, mining, and crushing machinery, to purchase the Bullock Co. This purchase 43 years ago marked the beginning of full scale manufacture of electric equipment by the Milwaukee Company.

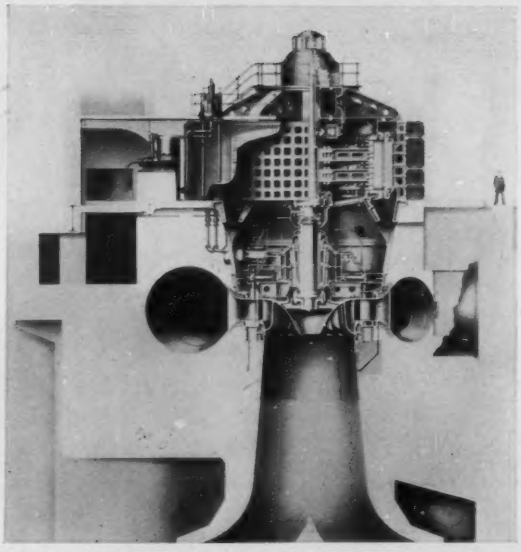


TYPICAL OF MANY THOUSANDS of long-lived Allis-Chalmers steam power units built in the past 70 years is this 500 kw steam turbine generating unit in daily service at Gillies Bros. Lumber Co., Braeside, Ontario. In 1907, it lighted Meriden, Conn. and was among the first commercial units built after A-C's entrance into turbine work in 1902. This record of service to steam power extends from the first Reynolds Corliss in 1877 to Chicago's 147,000 kw giant of today.

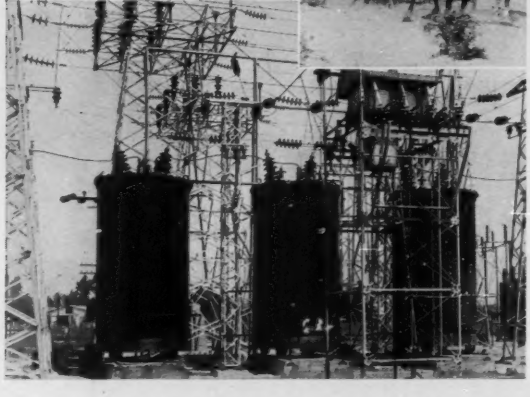
IN 1938 this 55,000 kw installation of Allis-Chalmers mercury arc rectifiers at the Aluminum Company of America's plant in Alcoa, Tenn., was by far the largest single rectifier installation in America at the time. This proved so successful that practically all electrolytic refining of the light metals is done with mercury arc units today. Then the total installed rectifier capacity in the U. S. was about one half million kw—today it is near three million.



THE FIRST METAL-CLAD SWITCHGEAR made in the U. S. was manufactured by Allis-Chalmers under Reyrolle designs in 1929. One of the first such installations of this very rugged armor-clad gear was this series of 1,500,000 kva, 15,000 volt breakers at Station No. 6, Waukegan Generating Co., Waukegan, Illinois. Less than twenty years have passed between this and today's almost universal acceptance of metal-clad high voltage gear.



WHILE MAINTAINING leadership in steam engine prime movers Allis-Chalmers was an early builder of hydraulic pumps and water-wheels. One of the great turbine engineering accomplishments was the 70,000 hp hydro generator built for Niagara Falls in 1922, at the time the largest power generating unit in the world.



ALLIS-CHALMERS-BULLOCK was also a pioneer maker of power, distribution, and furnace transformers. Early in 1912 these 60 cycle 4000 kva 87,000/150,000 volt water cooled transformers were installed at the Southern Sierras Power Co. at San Bernardino, California. It is interesting to note the bushing sizes that were considered safe practice for 150 kv in those days. Getting the transformer to the site wasn't an easy job either. The inset shows a 1913 scene—mules and men, and the old "high wheeler" along the desert trail.

In 1927 the Pittsburgh Transformer Company, another pioneer, became part of the Allis-Chalmers organization and the Pittsburgh plant was devoted exclusively to the manufacture of distribution, instrument, vault, and smaller power transformers.

Hydrogen Cooling Simplified

A. LEHRKIND
Electrical Engineer

W. F. KING
Mechanical Engineer

Electrical Department
Allis-Chalmers Mfg. Co.

HYDROGEN CONTROL equipment for this 80,000 kw, 1,800 rpm, hydrogen-cooled turbo-generator will require no vacuum treating apparatus. This new stator design incorporates four concentrically mounted coolers, reducing generator diamater and height above the floor line. **(FIGURE 1)**

Vacuum Treating of Shaft-Seal Oil Is Not Necessary For Maintaining Hydrogen Purity In Turbo-Generators

EVER since hydrogen gas under pressure in the casing was first used to increase the efficiency and reduce the size of turbo-generators, designers have striven to reduce the complex auxiliary apparatus that seemed to be necessary to insure safe operation.

Basically, two features are essential for hydrogen cooling of turbo-generators. First, the machine must have a gas tight, explosion-safe enclosure. Second, means must be provided for controlling the hydrogen charge to keep the gas pressure (and purity) within required limits.

From a practical standpoint, the degree of success attained in satisfying both of these requirements depended primarily on the development of efficient seals for the shaft openings in the housing. All hydrogen shaft seals are oil lubricated, and oil has an inherent characteristic of acting as a sponge. It absorbs as much as ten percent by volume of any gas to which it is exposed.

The most difficult problem introduced by this sponge-like nature of oil is not keeping the hydrogen in the machine but keeping air out. Any air entering the machine via the shaft seal oil during normal operation must be counteracted by an outflow of impure gas and its replacement by an equal volume of fresh hydrogen.

Suppose, for example, that during the course of each day four cubic feet of air should enter the housing. To maintain a hydrogen purity of 98 percent, it would be necessary to exhaust 200 cubic feet per day of 98 percent pure gas from the generator and to replace this with an equal amount of approximately 100 percent pure hydrogen. That is, when gas of 98 percent purity is removed, 200 cubic feet of the mixed gas must be removed to get rid of four cubic feet of air brought in by the seal oil.

Accepted hydrogen cooling practice called for the addition of vacuum treating equipment for removing the air from the seal oil. But experience was to prove that this contamination problem, and its consequent difficulties could be eliminated by a thrust bearing type of seal permitting only a small amount of oil to enter the hydrogen atmosphere, thus reducing contamination to a negligible minimum. Machines using this type of seal and built without any vacuum treating equipment have been in service for over six years. Other machines, on which vacuum treating equipment was provided, have been operating without any need for or use of the equipment furnished; the oldest of these machines have been in operation for nine years.

Consequently, all vacuum treating equipment has been eliminated from units produced within the last two years. Furthermore, experience with the stable operation resulting from the thrust type seal has resulted in further simplification of all hydrogen cooling auxiliaries, so that little more equipment is needed than for air cooling.

Design and operational benefits

The thrust seal has proved itself exceptionally versatile. It has been used without modification to seal generator housings at pressures ranging from a vacuum of 26 inches hg to the maximum required gas pressures. Its large, flat wearing surfaces permit close clearance which is no larger than the thickness of an oil film.

Most of the oil supplied to the seal is used for cooling; it is discharged through radial grooves into the bearing pedestals, without, at any time, coming in contact with hydrogen. A small quantity of the oil for sealing does enter the hydrogen atmosphere between the sealing ring and the shaft; while this oil carries a minute amount of air into the housing, the fresh hydrogen admitted to replace normal leakage is sufficient to maintain high purity. Loss of hydrogen into the oil system is

prevented by a detraining tank in the seal drain line. The oil flows through the tank slowly enough for the hydrogen to bubble out and return to the housing.

Practically all of the reduction in the amount of elaborate metering apparatus, alarm systems and other "gingerbread" associated with older hydrogen cooled turbo-generators must be credited to the shaft seal.

Development of shaft seal

As has already been mentioned, the component presenting the most difficult problems in design and development was the shaft seal. At the surface speed of a turbo-generator shaft it is necessary that the sealing be accomplished by an oil film between the shaft and a stationary surface. Oil then serves as a sealing medium, lubricant and coolant. Only a very small part of the oil may escape to the hydrogen side of the seal if the utmost in simplification of the seal oiling system is to be attained. Other requirements of the seal are that it shall have negligible wear and low power loss, permit axial movement of the shaft, and be suitable for temporary service at standstill without oil pressure, if necessary.

Extensive tests were run on two full size seals separated by a narrow gas enclosure. Performance of the experimental seals led to successive design modifications until the present seal design was evolved. Operating data was obtained over a wide range of gas and oil pressures to establish optimum operating conditions. Using oil saturated with air (oil will absorb up to 10 percent air by volume) the hydrogen scavenging rate necessary to maintain a given gas purity was checked for varying rates of oil flow to the hydrogen side of the seals. (See Figure 2a and 2b.)

A sectional view of the seal is shown in Figure 3. Essentially, it consists of a split babbitt-faced sealing ring bearing against a shaft collar or runner (1) located at the generator end of the bearing.

Oil for lubricating and cooling the seal is fed into the annular chamber (6) in the seal housing at a pressure of at least two psi higher than the generator hydrogen pressure. Oil passages (7) lead the oil to a circumferential groove in the babbitted seal face. Between the circumferential groove and the inner or hydrogen side of the seal is a continuous sealing surface (5), separated from the rotating surface by an oil film. The rate of oil flow to the generator side of the seal is only a few gallons per hour.

The seal face between the circumferential groove and the outer or air side of the seal is divided into a series of segments (2) by a number of radial grooves. The number and size of these grooves are designed to pass an adequate flow of oil for cooling the seal. This cooling oil discharges into the bearing enclosure and drains off with the bearing oil. Thrust load on the seals is supported by the segments which act as a thrust bearing.

During operation, the sealing surface is loaded in proportion to the oil pressure. Springs (3) keep the sealing surfaces in contact in case the auxiliary oil pumps should be shut down when the unit is not operating. A good seal can thereby be maintained at standstill without oil pressure for short periods at low gas pressure.

The seal ring can move axially in the housing to follow any change in location of the shaft shoulder caused by temperature variation or other factors.

This highly effective thrust bearing type of seal is very successful for the surface speeds encountered on turbo-generators and provides the only method thus far shown suitable for lubricating and cooling the sealing surfaces without having more than a trickle of oil exposed to the hydrogen.

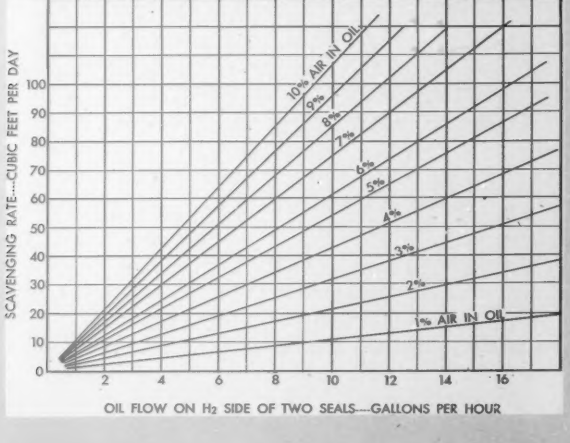
Since dilution of the hydrogen by absorbed air from this trickle of oil is offset by the hydrogen added to make up for normal leakage, vacuum treatment of the seal oil is unnecessary. The effectiveness of these improvements manifests itself in simplicity of the auxiliary equipment.

Simplified oil system

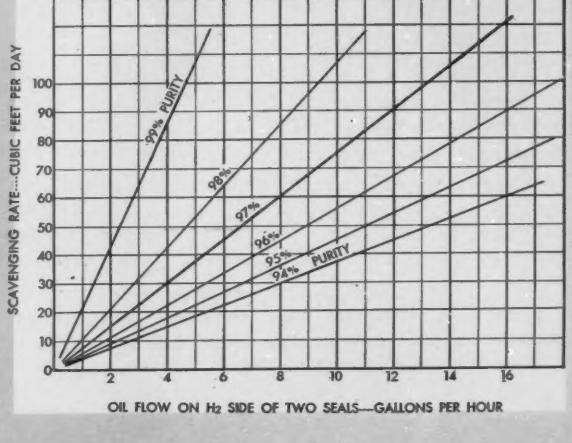
The modern shaft seal oil system for a hydrogen cooled generator (Figure 4) requires approximately forty gallons of turbine oil at a temperature of about 40 degrees C and the oil flow requirements vary from 10 gpm for a 15 megawatt generator to 40 gpm for a 100 megawatt machine. The highest temperature in the seal or seal system will not exceed 80 degrees C.

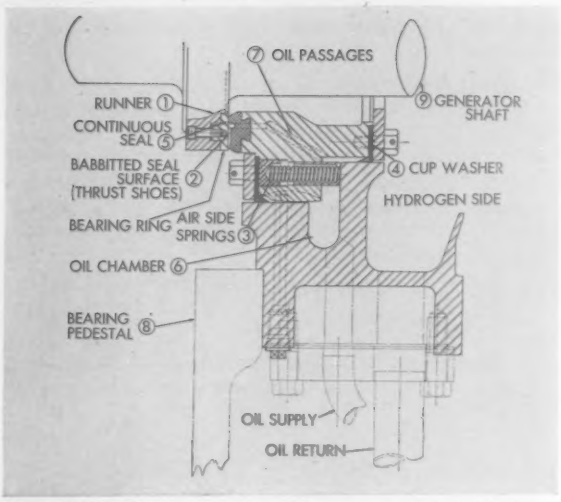
The oil supply for the seals is normally obtained from the turbine oil line. In the past the oil was supplied at sufficient pressure for sealing the hydrogen in the generator at pres-

SCAVENGING RATE in relation to oil flow on hydrogen side of seals for 97 percent H_2 purity and one to ten percent air in oil. **(FIGURE 2a)**



SCAVENGING RATE in relation to oil flow on hydrogen side of seals for seven percent air in oil and 94 to 99 percent H_2 purity. **(FIGURE 2b)**





SECTIONAL VIEW of a hydrogen seal for a generator shaft. **(FIGURE 3)**

sures up to three psig. Now, to permit 15 psig gas pressure for overload operation, oil is provided at a pressure of 20 psig for the seals.

Loss of pressure in the turbine oil line automatically starts the hydrogen seal oil pump, located at the turbine oil tank. This provides normal seal pressure independent of the turbine oil pumps.

Most of the oil used for lubricating and cooling the thrust faces of the seal discharges directly into the generator bearing drains. The small percentage of oil that flows past the sealing face and enters the hydrogen atmosphere flows to a detraining tank.

The detraining tank has sufficient volume to permit gravity separation of the oil and hydrogen. The oil slowly flows out through a float valve and U-tube trap, which prevents loss of hydrogen, and is returned by gravity to the main turbine oil tank. In case the float valve fails, the U-tube will hold hydrogen with pressure up to three psig, thus permitting emergency operation at low hydrogen pressure. The hydrogen returns to the generator through the seal drain pipes or through a separate vent pipe.

Simplified gas system

The hydrogen and carbon dioxide piping is easily traced in Figure 5. The gas cylinders and the four valves used for scavenging are usually located below the generator. Valve (26) admits carbon dioxide into the generator, while air escapes through valve (28). Pressure in the housing is held to a maximum of 18 psig to avoid overcoming the shaft seal oil pressure. A mercury U-tube gauge (63) is so placed adjacent to the cylinder manifolds that the operator can observe the machine pressure while operating the valves.

After the required amount of carbon dioxide has been admitted to safely flood out the air, valves (26) and (28) are closed, and valves (25) and (27) are opened. Enough hydrogen is then admitted to reach normal purity, and these valves are closed.

Valve (24) will then admit additional hydrogen automatically as required to maintain normal running pressure in the unit. For overload operation, by-pass valve (25) permits raising the pressure without resetting the reducing valves.

The pressure and purity gauges and alarm lights mounted on the operating panel can be located to suit operating convenience. (While details of the panel are shown in Figure 6, figure number references which follow still apply to Figure 5.)

Hydrogen purity checks

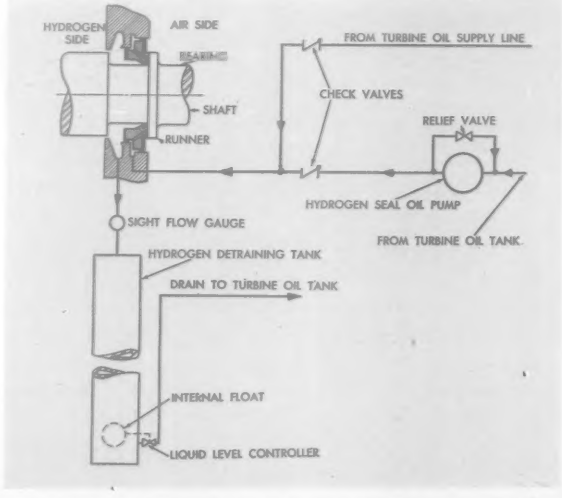
Hydrogen purity is determined from differential pressure gauge (65) or (66), for normal or overload operation, respectively. These gauges measure the pressure developed by the main generator fans. Since the fans run at constant speed, the pressure developed is directly proportional to the gas density. Because of the extreme difference in the densities of hydrogen and air, the proportion of each in a mixture of the two is easily determined by a measurement of the density of the mixture.

Gauge (65) is an inclined oil-filled U-tube and provides for easy direct reading of hydrogen purity when the generator is being operated at the normal pressure of ½ psig. Connected in parallel with gauge (65), vertical U-tube (66) is used for higher gas pressures; a convenient graph mounted on the panel permits direct conversion of the higher pressure readings to percentage of hydrogen.

Gauge (64), in the same instrument case, is a 36-inch mercury U-tube and indicates the machine gas pressure.

The valves on the panel are for convenience in testing the gauges. This is recommended as a daily procedure since the time required is almost negligible. The zero readings of all instruments on the panel can be checked rapidly by closing valves (31) and (32) and opening valves (30) and (38).

The alarm circuit diagram, Figure 7, shows the simplification of the electrical circuits resulting from the elimination of unnecessary instruments and vacuum treating. A multiple-contact switch permits simultaneous testing of the lights in the complete alarm light unit, which, with bell relay and test switch, is contained in a standard switchboard instrument case.



OIL SYSTEM for shaft seals of a hydrogen cooled generator. **(FIGURE 4)**

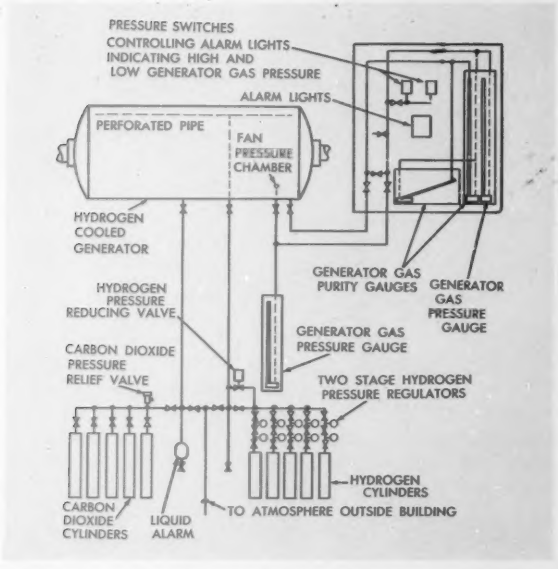


DIAGRAM showing hydrogen and carbon dioxide piping system. **(FIG. 5)**

Non-essentials eliminated

All equipment not essential to the operation of the hydrogen cooling system results in unnecessary operating and maintenance expense. Nine years of operating experience has shown conclusively that the following auxiliary apparatus in the hydrogen system is unnecessary with the thrust bearing seal:

I. A completely separate seal oiling system including:
   1. Vacuum tank with spray nozzles, float valves and gauges
   2. Vacuum pump with oil separator tank
   3. Seal oil cooler (on standard machines)
   4. Seal oil pump and motor for normal operation (a seal oil pump is needed as a standby for use when the turbine oil supply is shut down)
   5. Pressure regulator to control seal oil pressure in proportion to hydrogen pressure
   6. Numerous valves and alarms incidental to the above items

II. Superfluous items of hydrogen control equipment including:
   1. Recording or indicating gas purity meter other than a generator fan pressure gauge
   2. Hydrogen dryer unit
   3. Gas pressure gauge other than a mercury U-tube

III. A vapor extractor to remove hydrogen from the oil lines and turbine oil tank.

Scavenging methods compared

There are two safe and convenient methods of admitting hydrogen to the generator housing. One method utilizes a vacuum pump to remove air from the shell. Since no mixture of hydrogen with air can ignite below one-fifth atmosphere absolute pressure, evacuation to this pressure permits easy filling of the machine with a minimum amount of gas.

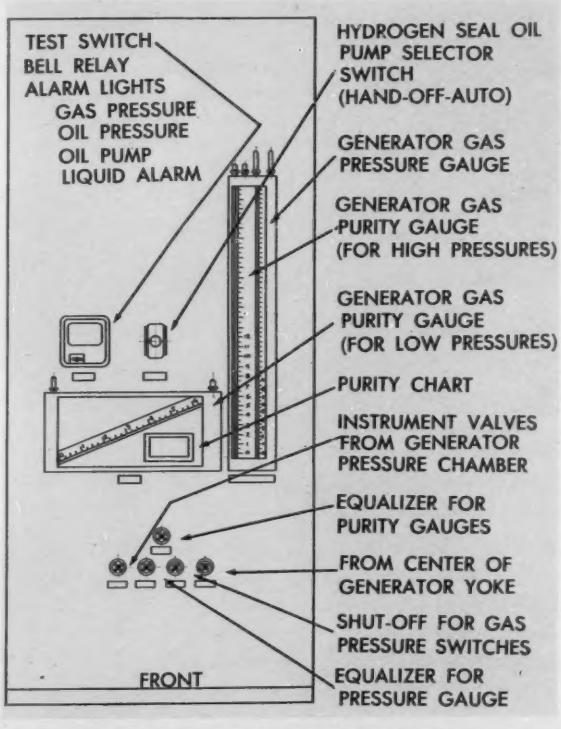
In the other method, an inert gas, such as carbon dioxide, is used to force air out of the machine. The admission of hydrogen then removes the inert gas and the machine is ready for operation. While this method requires considerably more gas than the vacuum scavenging method, it is generally accepted because of its simplicity in operation and equipment requirements.

With the carbon dioxide method of scavenging, a hydrogen purity of 98 percent is normally obtained; this is more than is required for operation at guaranteed efficiencies. Leakage of gas in the average machine is sufficient to balance the small amount of air carried in by the lubricating oil; a flow of a few cubic feet per day of pure hydrogen from the cylinders is sufficient to maintain hydrogen purity of about 96 percent in the housing. Because of this balance of flow, no separate automatic purity control is needed.

The complete gas system consists of two groups of gas cylinders, the necessary piping, some pressure regulating valves, pressure gauges, and pressure switches, plus a liquid operated switch for alarm operation.

In normal operation, gas is supplied automatically and the turbine operator merely observes gauge indications occasionally as part of the turbine operating routine. Experience in plant operation has been the determining factor in the elimination of elaborate recording and control apparatus in favor of this simplified equipment.

The initial commercial installations were taken directly from the laboratory with their complete apparatus for measuring, controlling, and recording operating conditions, plus



FRONT VIEW of a hydrogen instrument panel showing the arrangement of pressure and purity gauges and alarm lights. **(FIGURE 6)**

gauges for checking the recorders. Except for improvements in the arrangement and construction of component parts, subsequent early installations merely copied the first ones. Consequently, the equipment in them was bulky and much of it was eventually found to be superfluous.

Testing for leaks

Stator yokes and end housings are assembled and tested for leakage before the stator core is stacked. Leakage at properly prepared flanged joints is negligible. Leaks occasionally occur in welds and at pinhole flaws in the steel plates or castings. An accurate determination of the rate of leakage is necessary to insure that it is reduced to acceptable limits.

Large bolted flanged joints such as the joint between the end housing and the stator yoke are made gas-tight by injecting a non-hardening, highly viscuous sealant into a groove cut in one of the parting surfaces. If a leak should develop at a later date additional sealant can be injected into the groove to renew the seal. However, experience has shown that the initial seal will last indefinitely.

Leaks in the system after erection in the field can be perplexingly difficult to locate. These usually occur in the piping which is assembled at the site. The usual procedure for tracking down the leak is to isolate portions of the system, test for rate of leakage by checking pressure drop, and search for the leak with soap water or other means. Obviously, simplification of the piping reduces the likelihood of leaks and makes them easier to locate when they do occur.

Hydrogen cooling advantages reviewed

Tabulations of losses in high-speed, air-cooled machines show that windage accounts for a third to a half of the total losses, the proportionate share of windage loss increasing with the peripheral speed. This loss almost disappears when hydrogen replaces the air, for the extremely low density of hydrogen (.0696 that of air) reduces the windage loss by over 90 percent. Furthermore, hydrogen's high heat transfer coefficient (50 percent greater than that of air) reduces the amount of cooling surface required.

For complete safety of personnel, the generator, heat exchangers and fans are completely enclosed in a cylindrical shell capable of withstanding the worst possible explosion of hydrogen and air. This shell provides a rigid support for the generator, helps to reduce vibration and noise and, by eliminating external ductwork, saves power plant space.

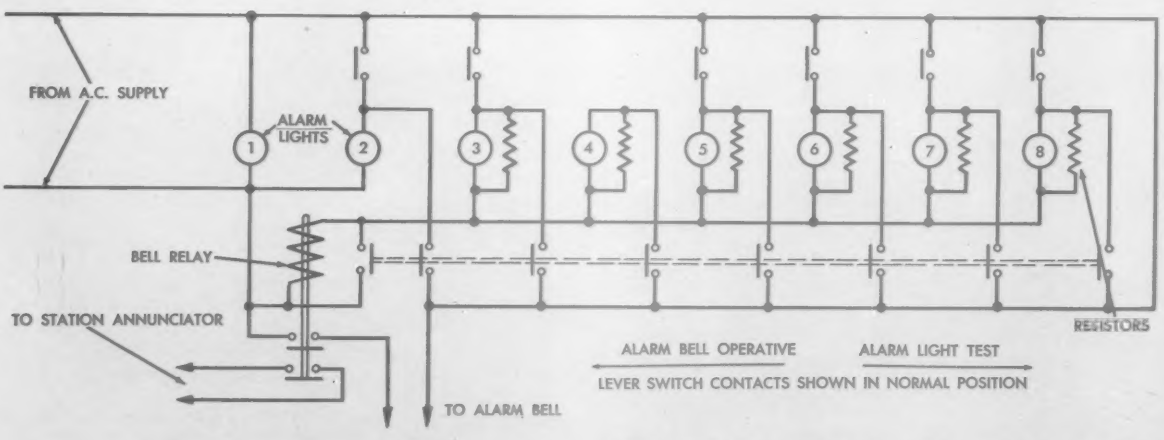
The virtual elimination of oxygen from the interior of the generator practically eliminates destructive insulation damage from ozone produced by corona. The gas-tight shell also eliminates overheating caused by accumulation of dirt in ventilating passages. It also reduces the possibility of destructive fires in the machine.

Operating experience

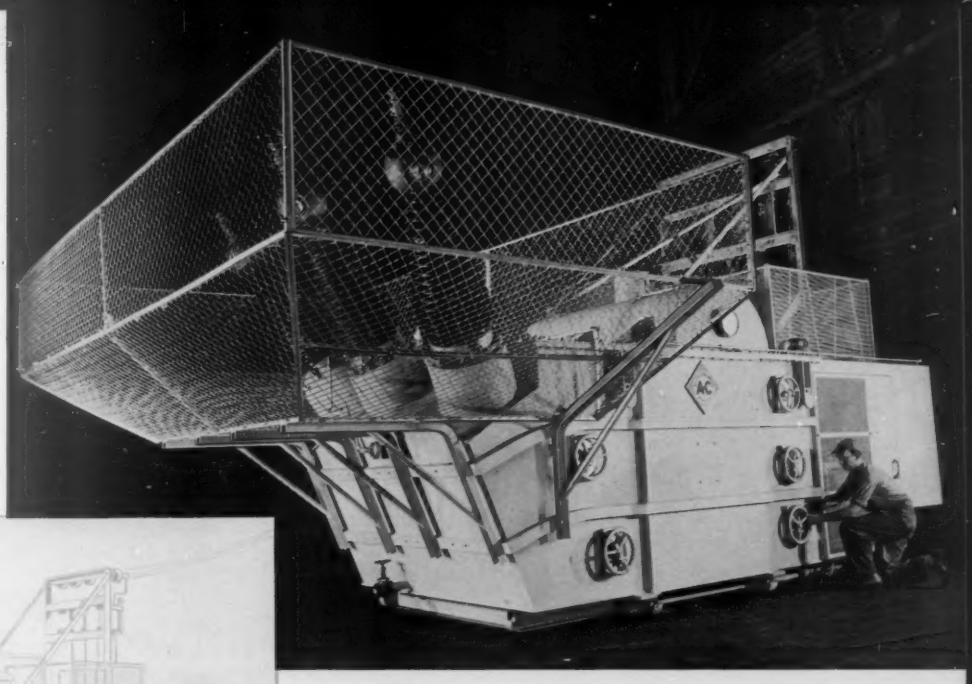
The excellent operating record of hydrogen cooled generators has resulted in a definite trend toward hydrogen cooling for all large high speed alternators. Most installations have included complete equipment for continuously recording hydrogen conditions as well as laboratory type gauges for checking the recording instruments. The seals used to prevent the escape of hydrogen where the shaft extends through the housing required new development for the speeds and sizes involved. The bulk of the extra equipment for hydrogen cooling was furnished to supply clean, cool de-aerated oil to the seals. All equipment was arranged so that it could be isolated from the system for testing or removed for repairs without interrupting normal operation.

Experience proved that much of the apparatus was superfluous, required more care than was justified and could be omitted without detrimental effects. Therefore, equipment for hydrogen cooling has been reduced to operationally proven essentials. The additional maintenance of hydrogen control equipment has been practically eliminated and the duties of the operators reduced to slightly more than for an air-cooled machine.

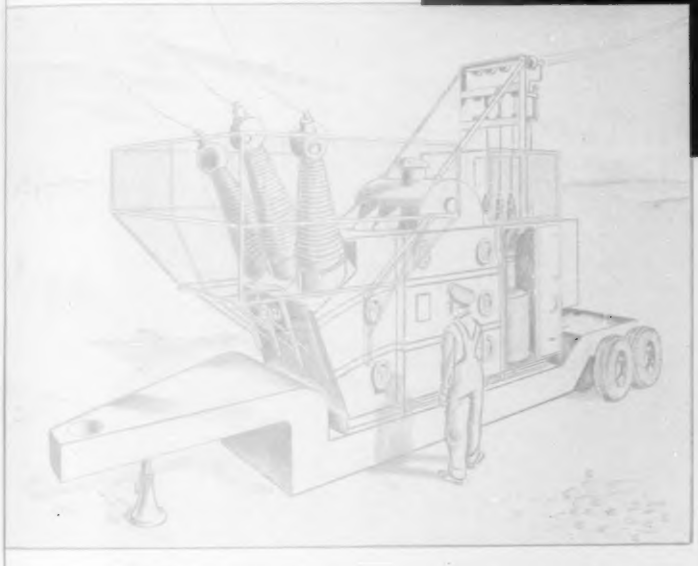
Hydrogen cooling has proven itself to be certain, safe, and simple. The "bugs" of the system have been exterminated and indications are that, in the future, hydrogen will be used in all large high speed generators and in many of the smaller units.



ALARM LIGHTS indicate engraving on translucent plate in front of light; a-c voltage; hydrogen seal oil pump; liquid alarm; hydrogen pressure, and hydrogen seal oil pressure. **(FIGURE 7)**



MOBILE SUBSTATIONS, such as this self-contained, trailer mounted 2,500 kva unit, provide efficient and economical tie-in facilities for use by utilities in power emergencies or network maintenance. **(FIGURE 1)**



110 KV on Wheels!

K. WIEDERKEHR
Transformer Engineering Section
Allis-Chalmers Mfg. Co.
and
R. LOEWE
Switchgear Engineering Section
Allis-Chalmers Mfg. Co.

Innovations in design and construction make high voltage mobile substations extremely versatile.

THE design for portable unit substations for very high voltages requires methods of construction which are often radically different from even those required for the lower voltage mobile substation. In common with all portable substations, minimum size and weight are essential to secure the largest possible kva rating without exceeding the allowable limits set by various highway laws. An example of what can be accomplished by a thorough engineering study in reducing space and weight is exemplified in the construction of the portable unit substation transformer described in this article. This unit has the following ratings:

2,500 Kva, 3 Phase, 60 Cycle

High Voltage — 110,000 v Wye — 63,510 v Delta — 55,000 v Wye — 31,750 v Delta, with all six 2½ percent full capacity taps.

Low Voltage — 2,400 v Delta — 4,160 v Wye — 7,200 v Delta — 12,470 v Wye — 13,800 v Wye.

Tertiary Voltage — 750 Kva — 5,000 v Delta.

In order that changes in voltage be made quickly in the field, all voltages are obtained without opening the transformer tank. This is accomplished by using series-parallel tap changers, delta-wye tap changers and tap adjusters for the taps in the high voltage windings. The series-parallel connection on the low voltage was accomplished by tap changers with six bushings brought out so that the delta-wye connections could be made externally. Connection diagram shown in Figure 2 illustrates the manner in which these voltages are obtained. All tap changers are provided with externally operated hand wheels. The tertiary winding is utilized only for harmonic suppression and remains closed.

Weight and size limitations

To conform with clearance and load limitations on principal highways under special permit, the following space and weight limits for portable unit substations were established:

Physical characteristics

Overall Semi-Trailer Width.....8 ft
Spread between Hi-Voltage Bushings.....9 ft, 6 in
Overall Height (In Transit).....10 ft, 3½ in
Overall Length.....21 ft, 6 in
Total Weight (In Service with Oil).....60,000 lb
Semi-Trailer Weight (In Transit).....50,000 lb

In order to reduce the total weight of the substation to 50,000 pounds for transit, and to reduce the width to allowable limits, guards placed around the high voltage bushing are removed and carried on a separate trailer; oil is removed from the main transformer tank and carried in an auxiliary oil tank on a separate trailer. A comparison with a conventional stationary unit of the same size and characteristics indicates a necessity for radical departures in accepted design to meet special requirements. The weight of an equivalent standard transformer is approximately 45 percent greater and the cubical contents approximately 50 percent larger. Only by radical digression from past design practice can one expect to design a unit to meet the size and weight limitations required for the application.

Transformer construction

The main core and coils are shell type with circular coils and with the three phases arranged in line across the width of the tank. Because of the cubical content required by the tap changers, it was necessary that they be placed in front and in back of the core and coils on the trailer to reduce crossings of electrical connections to a minimum. By careful design most high voltage leads are arranged for a direct run from the coil to the delta-wye and series-parallel tap changers and then to the bushings on the same side.

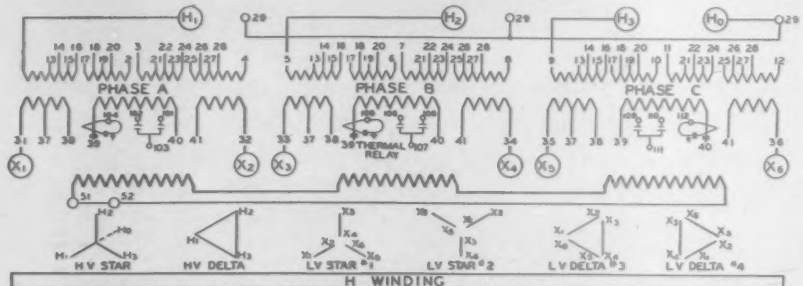
High voltage tap changers for the 2½ percent taps are placed on the low voltage side of the transformer near the bottom of the tank. The low voltage tap changer for the low voltage series-parallel connection was placed above the high voltage tap changers on the low voltage side. The leads from it run to the low voltage bushings located in the end of the tank inside the switchgear housing and are fastened to the low voltage end of the tank. The location of the various tap changers is shown in Figure 2.

The high voltage bushings are equipped with capacitance taps which fix their overall length. Bushings could be shortened only at the expense of less energy in the capacitance divider units. To save oil and, also, to reduce the height to the nine-foot overall height allowance, the bushings are located at an angle below the tank cover in an extension of the tank. Each bushing is placed on an individual collar to reduce the amount of oil required. The live parts of the bushings are surrounded by removable, high screens to prevent personnel from accidental contact with them.

The transformer has a typical multi-cruciform core to fit inside of the round coil. Reduction in size and weight was accomplished by using low-loss preferred oriented steel. The core extends from one side of the tank to the other with sufficient clearance to allow for tanking and untanking. It is held in place by an offset in the tank which also aids in tanking the unit. The end frames are of welded construction. Coils are clamped by means of threaded bolts, with individual jack screws between phases to permit individual tightening of each phase.

Tap adjusters

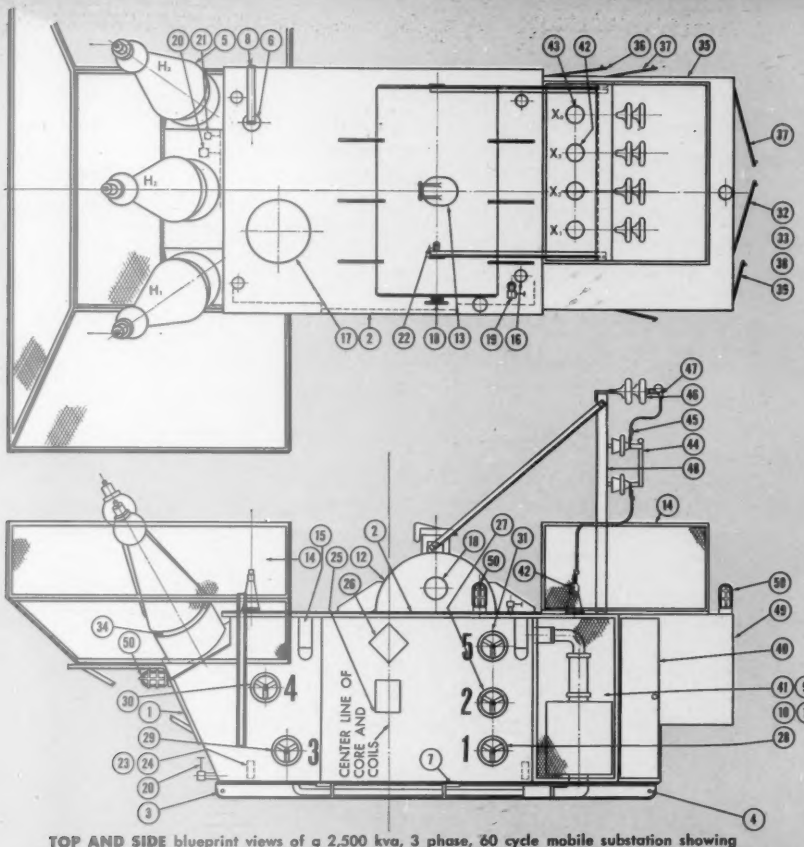
Two 110,000 volt tap changers with contacts connected to the line end are required: one to obtain a delta-wye connection and the other a series-parallel connection. New design for these switches were developed to reduce space and oil weight and still maintain space requirement for insulation clearances. Special construction was used to keep spacing between live parts down to a minimum. Dielectric flux control shields were employed to reduce the distances required. Figure 4 shows the series-parallel tap changer at the bottom and the delta-wye tap changer at the top. Figure 5



H WINDING										
Y CONNECTED RATIO ADJUSTER IV ON A CONNECTS H_1 TO 1; H_2 TO 5; H_3 TO 9; H_0 TO 4 TO 8 TO 12		DELTA CONNECTED RATIO ADJUSTER IV ON B CONNECTS H_1 TO 1 & 12; H_2 TO 4 & 5; H_3 TO 8 & 9		RATIO ADJUSTER I		RATIO ADJUSTER II		RATIO ADJUSTER III	
VOLTS H_1 TO H_2 TO H_3	AMP.	VOLTS H_1 TO H_2 TO H_3	AMP.	ON	CONNECTS ALL 3 PH.	ON	CONNECTS ALL 3 PH.	ON	CONNECTS
115 500	12.5	66 684	21.6	A	16 TO 17	A	24 TO 25		
112 750	12.8	65 097	22.2	B	15 TO 17	B	23 TO 25		
110 000	13.1	63 510	22.7	C	15 TO 18	C	23 TO 26		
107 250	13.5	61 923	23.3	D	14 TO 18	D	22 TO 26	A	2 TO 3 6 TO 7 10 TO 11
104 500	13.8	60 336	24.0	E	14 TO 19	E	22 TO 27		
101 750	13.8	58 749	24.0	F	13 TO 19	F	21 TO 27		
99 000	13.8	57 162	24.0	G	13 TO 20	G	21 TO 28		
57 750	25.0	33 342	43.2	A	16 TO 17	A	24 TO 25		1 TO 3
56 375	25.6	32 548	44.4	B	15 TO 17	B	23 TO 25		2 TO 4
55 000	26.2	31 755	45.4	C	15 TO 18	C	23 TO 26		5 TO 7
53 625	27.0	30 961	46.6	D	14 TO 18	D	22 TO 26	B	6 TO 8
52 250	27.6	30 168	48.0	E	14 TO 19	E	22 TO 27		9 TO 11
50 875	27.6	29 374	48.0	F	13 TO 19	F	21 TO 27		10 TO 12
49 500	27.6	28 581	48.0	G	13 TO 20	G	21 TO 28		

X WINDING					
		RATIO ADJUSTER X WDG.		BUSHING CONNECTIONS	
VOLTS	AMP.	ON	CONNECTS ALL 3 PHS.	FOR ⅄ FIG. 1	FOR Y FIG. 2
13800 Y	105	A	38 TO 39 ; 40 TO 41		
12470 Y	116	B	37 TO 39 ; 40 TO 41		
4160 Y	347	D	31 TO 39 TO 41; 32 TO 40 TO 37 PH.A 33 TO 39 TO 41; 34 TO 40 TO 37 PH.B 35 TO 39 TO 41; 36 TO 40 TO 37 PH.C	LINES ON $X_1 - X_3 - X_5$ NEUT. ON X_2 TO X_4 TO X_6	LINES ON $X_6 - X_2 - X_4$ NEUT. ON X_1 TO X_3 TO X_5
				FOR ◁ FIG. 3	FOR ▷ FIG. 4
7200 DELTA	201	B	37 TO 39 ; 40 TO 41		
2400 DELTA	602	D	31 TO 39 TO 41; 32 TO 40 TO 37 PH.A 33 TO 39 TO 41; 34 TO 40 TO 37 PH.B 35 TO 39 TO 41; 36 TO 40 TO 37 PH.C	X_1 & X_6 LINES X_2 & X_3 X_4 & X_5	X_1 & X_4 LINES X_3 & X_6 X_2 & X_5

DIAGRAM showing winding connections and arrangement of 24 primary and 5 secondary taps in typical mobile unit. **(FIGURE 2)**



1. TANK
2. COVER
3. BASE
4. 1½" DIA. PULLING EYES
5. HV LINE BUSHING – 115KV WITH CAPACITANCE TAP
6. HV NEUTRAL BUSHING – 15KV
7. JACK BLOCKS
8. ¼"x2" BUS BAR
9. HEAT EXCHANGER WITH LIFTING EYE
10. OIL PUMP
11. RADIATOR VALVES WITH BLANK FLANGES
12. EXPANSION TANK
13. RELIEF DEVICE DIAPHRAGM AND ALARM CONTACTS
14. REMOVABLE PROTECTING SCREENS
15. HOOKS FOR LIFTING COMPLETE UNIT
16. EYE NUTS FOR LIFTING COVER ONLY
17. MANHOLE
18. MAGNETIC OIL GAUGE
19. FILTER PRESS VALVE – 2" GLOBE
20. DRAIN AND FILTER PRESS VALVE – 2" GLOBE
21. SAMPLING VALVE – ½" ANGLE WRENCH OPERATED
22. UTILITY VALVE – ½" GLOBE
23. 2 GROUNDING CONNECTIONS
24. 2 CLAMP TYPE, 2 BOLT TERMINALS
25. NAME AND DIAGRAM PLATE
26. A-C MONOGRAM PLATE
27. HANDWHEEL FOR RATIO ADJUSTOR I
28. HANDWHEEL FOR RATIO ADJUSTOR II
29. HANDWHEEL FOR RATIO ADJUSTER III
30. HANDWHEEL FOR RATIO ADJUSTER IV
31. HANDWHEEL FOR RATIO ADJUSTOR – X WINDING
32. OIL TEMPERATURE INDICATING THERMOMETER WITH ALARM CONTACTS
33. RECORDING THERMOMETER
34. CAPACITANCE TAP CONNECTION
35. COMPARTMENT FOR AUXILIARY EQUIPMENT
36. DOOR FOR LV – Y TERMINAL BOARD
37. DOORS FOR OIL CIRCUIT BREAKER
38. DOOR FOR CONTROL AND METERING EQUIPMENT
39. DOOR FOR POTENTIAL TRANSFORMER
40. DOOR FOR INERTAIRE EQUIPMENT
41. SCREEN FOR IT'S 9, 10 and 11
42. LOW VOLTAGE BUSHING 15KV
43. LV NEUTRAL BUSHING 15KV
44. THREE 15 KV, 600 AMP SINGLE POLE DISCONNECTS
45. CLAMP TYPE LINE TERMINAL
46. SUSPENSION INSULATOR 15KV
47. CLAMPS FOR DEAD ENDING LINE
48. REMOVABLE MAST
49. EXTERNAL DANGER LIGHT AND WARNING SIGN
50. WEATHER-PROOF LIGHTING FIXTURES

TOP AND SIDE blueprint views of a 2,500 kva, 3 phase, 60 cycle mobile substation showing location of principal components. These portable units supply tie-in facilities ranging from 2.4 to 13.8 kv distribution voltages and from 31 to 115 kv transmission voltages. **(FIGURE 3)**

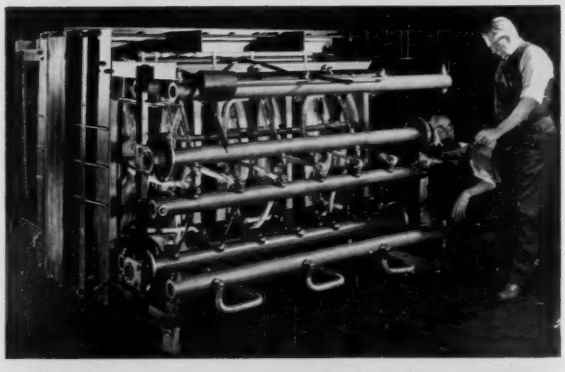
shows the two rows of high voltage tap changers, one for each of the two high voltage tap groups at the bottom and the low voltage series-parallel tap changer at the top.

Cooling system

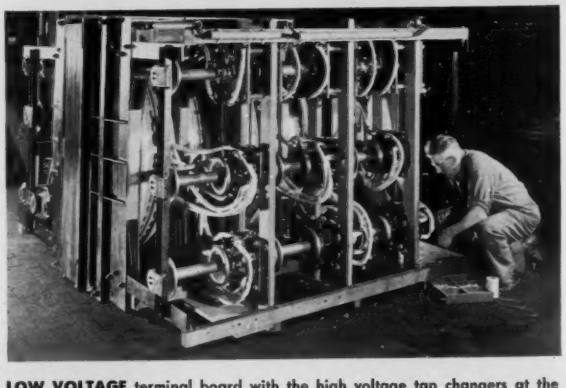
An air-cooled oil circulating system, similar to that used during the war on almost all large power transformers, was selected to save weight. It consists of a heat exchanger and oil pump circulating the oil from the top of the transformer tank through the heat exchanger and back into the bottom of the tank, with a large propeller type fan blowing air through the fins of the heat exchanger. To force the oil past the core and through the coil duct, baffles were installed on the top and side of the transformer. The oil outlet is located on one side of the transformer and the oil inlet on the other, as shown in Figure 7. The heat exchanger and pump, together with the necessary control and protective relays, are located in the switchgear housing.

Inert gas system

The transformer is equipped with a high pressure inert gas system with the domed section in the cover, shown in Figure 3, serving as an expansion tank with relief device on top. This construction was selected rather than a uniform section of expansion over the complete tank area because it offered an ideal opportunity to brace the cover for vacuum without the use of extra material. Also, this construction permitted building the transformer close to the cover with consequent saving of considerable head room. To cool core and coils

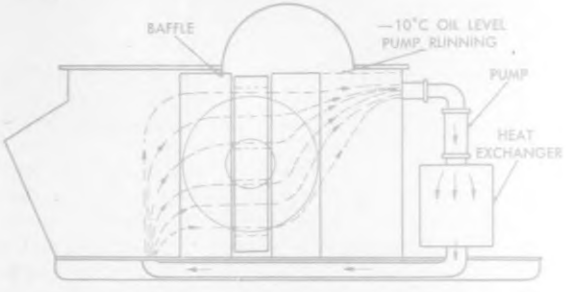


HIGH VOLTAGE terminal board for a portable substation. **(FIGURE 4)**



LOW VOLTAGE terminal board with the high voltage tap changers at the bottom and low voltage series-parallel tap changer at the top. **(FIGURE 5)**

INTERIOR of control compartment, with panel swung out, shows method of wiring. A removable barrier covers cubicles for control fuses during operation. Warning light above panel lights only when the substation is energized. **(FIGURE 6)**



OIL FLOW DIAGRAM illustrates the air-cooled oil circulating system used for properly cooling substation core and coils. **(FIGURE 7)**

properly it is essential that both are immersed in oil at all operating temperatures. The low temperature oil level is located at the under side of the cover slightly above the top of the core. When the oil circulating pump is started, the oil level will tend to drop on the suction side of the pump near the top of the core. In the meantime, the oil on the inlet side will tend to raise but, since the oil level on this side is already up to the top, oil will be forced through the transformer to the outlet side into the expansion tank (Figure 7). The high pressure reducing valves with pressure gauge and nitrogen cylinder for the inert gas system are located inside the switch-housing with gas inlet and sampling connection leading into the expansion tank.

Oil storage tank

It was not possible to design a portable substation of the capacity voltage class, and special requirements, within the 50,000-pound permissible weight limitation without the use of light weight material. To reduce the total weight of the substation to the allowable limit while in transit, a second trailer will carry an auxiliary oil tank for storing the excess oil from the substation transformer. The oil storage tank is equipped with necessary nitrogen cylinders, pressure reducing valves and flexible hoses to connect to the transformer tank. To empty the oil from the transformer, the flexible hose of the auxiliary tank is connected to the main drain valve and nitrogen under pressure is admitted through a flexible hose into the gas sampling valve on top of the transformer, transferring the oil to the auxiliary tank. After the substation has reached its destination, the oil is transferred back from the auxiliary oil tank to the transformer tank by reversing the procedure described above. The change-over is accomplished in a short time and the transformer is kept dry and in good operating condition at all times.

Many deviations from standard design practice are necessary in such units as this in order to meet space and weight requirements. This is as true for the secondary switching equipment as it is for the transformer.

Entire unit streamlined

The problem of special design to reduce space and weight was not limited to the transformer portion of the substation, but to the entire unit including switchgear and metering equipment.

Welded to the low voltage end of the transformer is a sheet steel enclosure containing the metering, switching and control equipment. The peculiar shape of the enclosure is due to the necessity of fitting to the shape of the trailer on which this substation is carried.

The switchgear housing is divided into a number of separate and distinct compartments. Each one is isolated from the other by sheet steel barriers and is accessible either through bolted-on barriers or lockable doors. These compartments are as follows:

1. Inert gas equipment
2. Heat exchanger equipment
3. Potential transformers
4. Current transformers
5. Low voltage wye-delta terminal board
6. Control transformers
7. Control and metering
8. Oil circuit breaker

Design and accessibility

Located in one of the outer compartments, the heat exchanger and associated equipment is protected by a removable galvanized screen. This equipment is in constant operation when the substation is energized.

The current transformer compartment, located behind the cooling equipment, is accessible through barriers which can be easily removed. These current transformers furnish power for relaying and metering and each is equipped with two separate and distinct secondaries of different ratings. It is to be noted that the current transformers are so arranged that when the substation is connected for a delta secondary, they will be within the delta. This allows the same three-element watthour meter to be used without reconnection of its circuits.

On the side opposite the cooling equipment is a compartment housing a wye-delta terminal board with connections from the six bushings on the transformer, the neutral bushing on the roof and the three leads from the oil circuit breaker. Output of the station can be connected for either wye or delta operation by means of removable links and, furthermore, the secondary connection can be made to either lead or lag

the primary by 30 degrees as may be necessary at any individual installation of the substation.

The transformer inert gas equipment is also contained in the switchgear portion of the station. All of the equipment for controlling the supply of gas to the transformer, as well as the gas bottle itself, is housed in a separate section and readily accessible through a hinged door.

The three potential transformers and their fuses are located in another section. The fuses are of the current limiting type adequate for the maximum short circuit duty. Six are provided and mounted in individual insulated fuse holders. Each transformer has a three-part primary winding arranged to be connected in series or parallel as required. The secondaries are also provided with one tap. This combination allows the matching of potential transformer ratio to output voltage of the station.

The high voltage portions of the secondary oil circuit breakers are separately housed away from its operating mechanism. This is also accessible through a hinged door.

Between the current transformer and control compartments is a section, shown in Figure 6, containing the two station service transformers and their primary fuses. The fuses are of the disconnecting type and can be removed and handled by means of a conventional type of fuse stick. The two transformers are of the dry type with Class "B" insulation and, like the potential transformers, are provided with three-part primaries and links for easy connection in either series or parallel as may be required to match the voltage of the station. When necessary, this equipment can be reached through a number of bolted-on panels.

Control equipment

Immediately in front of this section is the control compartment containing the oil circuit breaker solenoid operating mechanism, a swinging control and instrument panel and other miscellaneous control equipment.

Four 15 kv bushings to carry the neutral and the three-phase leads are mounted on the roof of the switchgear section. A rack with three hook-stick operated disconnect switches and strain insulators for terminating the outgoing overhead lines is mounted above the bushings. Surrounding the rack and bushings is a galvanized fence giving protection to the public when the station is in use. Both the fence and the rack are demountable while the station is being moved.

The oil circuit breaker is closed by a rectified alternating current from one of the station service transformers and tripped by a capacitor trip device. The breaker may also be closed and tripped manually. After the breaker is closed while the station is energized, it will automatically reclose when tripped providing the automatic reclosing relay is in service. A switch is provided for this purpose. The number of automatic reclosures is adjustable from one to three, with varying time delays between reclosures. The breaker will trip automatically for overload or short circuit, either phase or ground, excessive transformer temperature, failure of either electro-cooler motor or operation of the pressure relief device. Automatic tripping flashes an indicating lamp and rings an alarm bell. A switch is provided to temporarily silence the bell.

Power distribution

Metering equipment consists of three ammeters, a recording voltmeter, a recording watthour demand meter and a varhour meter complete with testing equipment.

The two station service transformers provide three-phase power for the heat exchanger and single-phase power for space heaters, compartment lights, external lights and a red glass warning sign to show when the station is energized. Power for all of these purposes is distributed through small thermal circuit breakers.

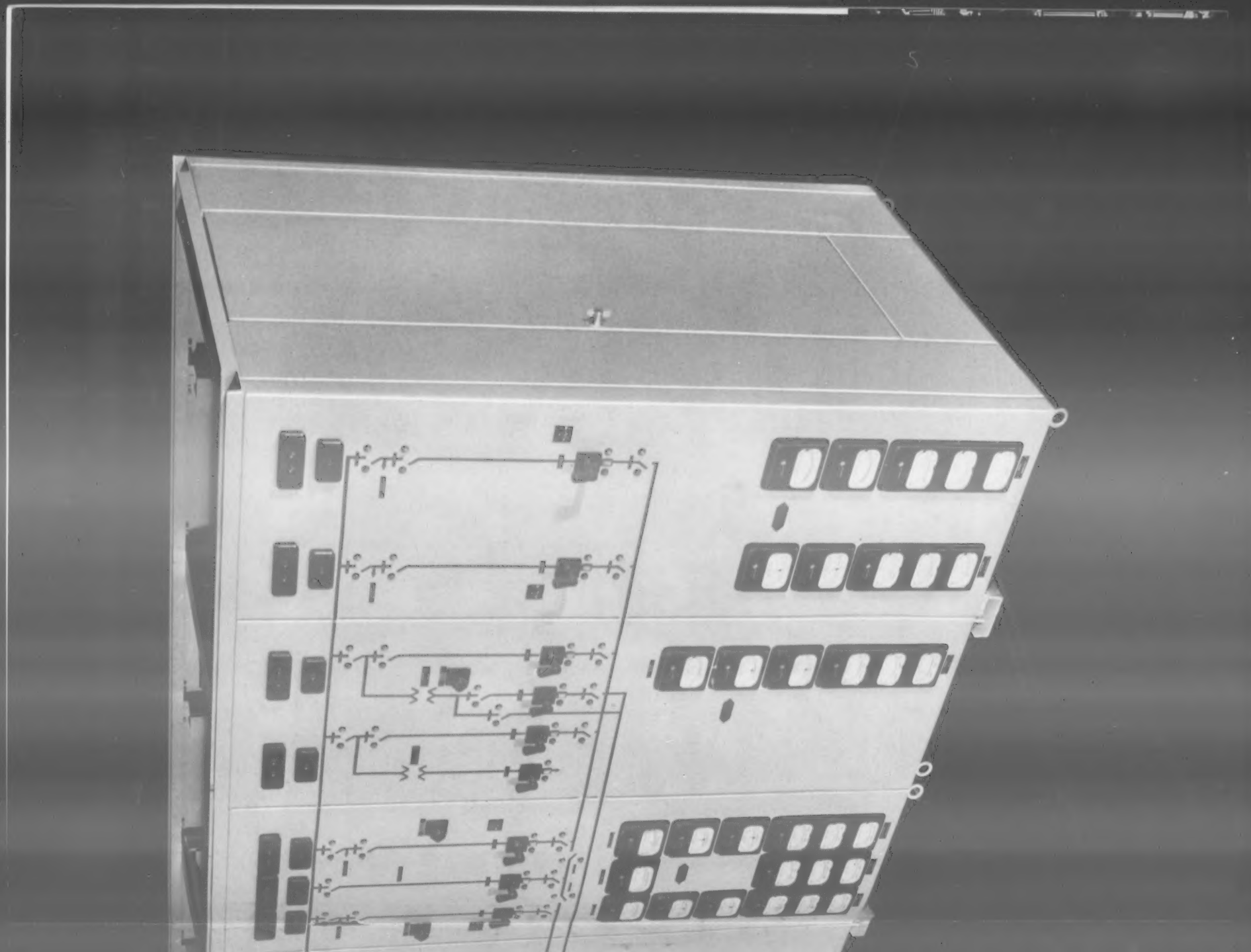
Because of the multiplicity of voltages and possible connections, numerous warning plates and connection diagrams are provided to warn operators and prevent possible errors. All compartment doors are equipped with padlocking devices to prevent unauthorized access to live parts and make a safe installation.

In spite of the multiplicity of voltage connections available and the necessary control reconnections which must sometimes be made, speed of getting the unit in service has been kept in mind throughout the entire design. Layout of all the demountable equipment is such that a minimum of bolts is necessary to hold it together. Terminal boards are quickly accessible with complete instructions and connection diagrams at the point of installation. In normal service, it is expected that a crew of four men will be able to place the substation, fill transformer oil, erect strain insulator racks and make line connections, put guard fences in place, make all necessary tap changes, together with control interconnections, and put the unit on the line in less than two hours, not including time in transit.

Preliminary investigations indicate that considerable additional saving in weight at additional cost could be accomplished in mobile substations by the use of light-weight aluminum or magnesium alloys in the supporting structure. Still further reduction could, of course, be obtained by permitting the losses of the transformer to be higher and by designing for higher temperature rise of the transformer.

This compact substation is suitable for a wide variety of conditions so that it can be used anywhere on one of the country's largest utility systems made up of many different transmission and distribution voltages. The station is equipped to be fully automatic in its operation, completely self-sufficient and self-contained. It is a means of supplying power to temporary customers for loads of short duration or of replacing power transformers on the system in the event of outage due to failure or maintenance requirements. Because of its unusual flexibility, this single mobile substation will save many times its own cost by greatly reducing investment in spare transformers, assuring emergency tie-in facilities anywhere on the system on a few hours' notice.

THIS ATTRACTIVELY styled tunnel-type duplex switchboard is being prepared for shipment to a large utility in Tennessee. Back-to-back panels, continuous wiring, and concentration of instruments and controls for convenient operation and inspection contribute considerably to the widespread acceptance of the tunnel-type board for secondary control.



ALLIS-CHALMERS

Do You Know Your Own Invention?

DIDIER JOURNEAUX
Patent Attorney
Allis-Chalmers Mfg. Co.

Before being patented, inventions should be checked for hidden features and ideas they may contain.

AN ENGINEER who makes an invention relating to his everyday work may meet difficulties in developing it, but at least he is on familiar ground. However, when he goes through the routine of patenting his invention, he generally finds the procedure beyond his comprehension, at least if he has had no previous experience with patent law. There is nothing very surprising about that. Patent law unites technology and law, and while this union has proved highly fruitful, the conjoints are rather ill-assorted and, in fact, hardly speak the same language.

Even after our inventor has become inured to the peculiar language in which his invention is described in a patent application, he is often bewildered by the multiplicity of features ascribed to his invention. It seems as if his brain child had gotten out of hand, and suddenly grown up beyond reasonable expectations.

But after the patent has been issued, the picture is apt to be different. Our inventor may have thought that his patent would give him a safe corner on some novel article of commerce. Yet he may live to see his competitors manage to market similar articles, of which he may or may not have thought, but which do not infringe upon his patent.

Such disappointments can be reduced to a large extent by a timely and thorough analysis of the invention by the inventor and his patent attorney. This often resolves itself into finding out what the invention actually is about.

Origin of invention

Let us assume that our inventor is a designer in a manufacturing plant. He may get the basic idea for his invention from a realization of some shortcoming of current production. The invention may also be made to order, one might say, for meeting special requirements of a customer.

In any event, an invention may generally be considered to comprise two fairly distinct mental acts. One is a more or less definite conception of a result to be obtained. The other is the provision of some means for obtaining the desired result.

But the inventor is not generally interested in such metaphysical considerations. His first concern is to put his invention to work. So, at the first opportunity, he has shop drawings made of what, to his way of thinking, is his invention, and he sends prints to the shop. If he thinks enough of the invention, he may also send a set of prints to his patent attorney. The latter is fortunate if he also receives a reasonably complete description of the invention and of its mode of operation, its background, and something of the history of its development. All this, put together, forms a so-called disclosure.

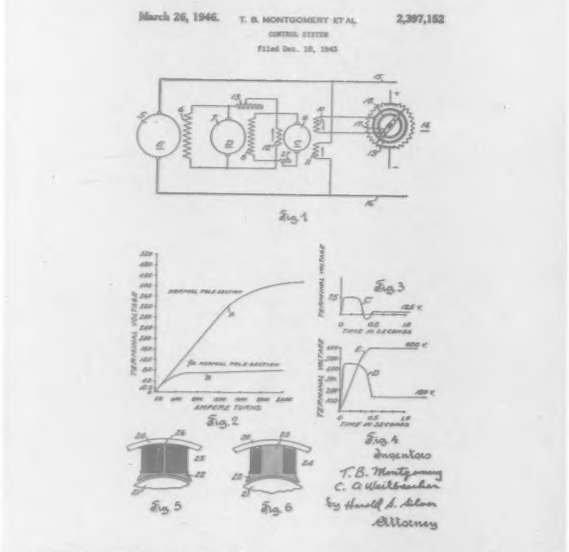
Definition of invention

At this point, the hunt for the invention is on. Of course, the quarry should meet the definition of patentable invention recognized by the Patent Office. Patentable invention is defined in a backhanded way, in the patent statutes, which provide that "Any person who has invented or discovered any new and useful art, machine, manufacture, or composition of matter, or any new and useful improvement thereof" may, under prescribed conditions, obtain a patent therefor.

This looks clear and simple enough at first view but, like most definitions, it can seldom be made to fit individual cases without a bit of twisting.

The result is that many technological developments, which ultimately became important, were considered at first as not involving invention. Long legal battles were necessary to ascertain whether they came within a class named in the statute.

In this connection, the greatest trouble maker is the harmless-looking keyword "new." To put it simply, at the risk of being inaccurate, a "new" device should be neither a Chinese copy of an existing device nor an obvious modification of it. The "obvious" is supposed to be what can be expected of the average technician in his particular field. But as nobody has so far been able to set up a standard for average technicians, it is often uncertain whether a particular modifica-


March 26, 1946. T. B. MONTGOMERY ET AL. 2,397,152
CONTROL SYSTEM
Filed Dec. 18, 1943
Fig. 1
Fig. 2
Fig. 3
Fig. 4
Fig. 5
Fig. 6
Inventors
T. B. Montgomery
C. A. Weidbacher
by Harold A. Adam
Attorney

CLAIMS OF PATENT 2,397,152 are directed to a system including a control exciter in which the field winding arrangement and the saturation of properly dimensioned field poles result in forcing of the exciter voltage and delayed damping action.

tion is "obvious" or not. The battle is therefore merely over one word instead of another.

To be sure, from a comparison of the disclosure submitted by the inventor with what others had done before, some preliminary conclusion may be reached as to which features might be "new." In such an investigation, the word "new" assumes a more practical aspect. A feature may be looked upon as "new" if it appears from past experience that allowance of claims involving the feature may be expected in a patent application.

Finding the invention

With that purpose in mind, finding the invention involves more than merely cataloguing the presumably new features of the disclosure which are obviously essential. It also calls, in the first place, for a determination of the broadest scope of the invention. This means finding out all the limitations which may be omitted from the broadest claims. This is, in a way, a negative method of finding the invention. It should be accompanied by its positive counterpart, working out a variety of equivalent arrangements, bearing in mind that the most important equivalents may be worth illustrating and claiming. Often it is also useful to try to figure out different ways in which competitors are likely to try to "get around" the patent, if, and when, the latter is granted. In spite of the old proverb, a prospective patentee should count his chickens before they are hatched; but he should count the foxes as well.

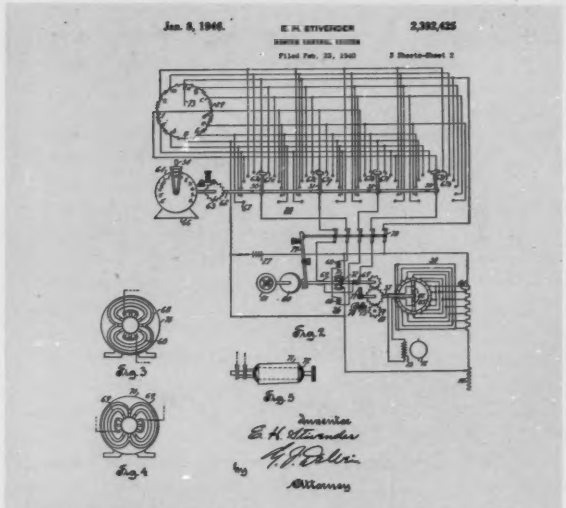
If the inventor can keep these different points of view in mind, he sometimes admits that there is more to his invention than what he has shown in his disclosure. In most instances, the latter merely shows one embodiment of the invention as the patent attorney would say, or, to put it in engineering language, a particular application. Anyway, the disclosure is merely a starting point in a systematic search for the invention.

To avoid becoming lost in generalities, let us assume that the disclosure is a diagram of an electrical system, be it of generation, distribution, or control. Such systems possibly require a more thorough analysis than any other invention. To a surprisingly large extent, simple basic electrical systems for most purposes were invented in the early days of the electrical industry, a good many of them by Thomas A. Edison. The result is that in many improvements made today along the same lines, novelty implies complexity. Besides that, diagrams of electrical systems often show incompletely many complicated pieces of machinery, so that essential details may become lost from sight.

Equivalent means

The system of the disclosure, it may be assumed, was developed to provide some means for solving a particular problem. It is generally profitable to inquire what other means could be used for solving the same problem. For example, if the system utilizes electromagnetic devices, it may be possible to devise equivalent systems utilizing instead dynamo-electric machines, electronic devices, or pneumatic, hydraulic or other mechanical means.

If the system contains fixed and movable elements, equivalent systems may be devised by making fixed the movable element and vice versa. Other variants can be devised by



FOLLOW-UP SYSTEMS having numerous novel features which include specific dimensions of elements, staggering of transmitter contacts, single contact transmitter, compensation of circuits of idle receivers, provision of different stop arrangements, and various relations between transmitter and receiver movements are claimed in Patent 2,392,425.

other such "reversal of parts" between elements of the system. Although they are not always worth claiming or even illustrating, they should be kept in mind to make sure that the claims written in the application are broad enough to cover them.

Sometimes an electrical system inherently operates only on one kind of current, be it direct, single phase or polyphase. If equivalent systems operating on other currents can be devised, it may become apparent that the invention should not be restricted to one kind only. Useful alternative systems thus can be discovered more or less automatically. Such alternative systems may be the basis for valuable claims. They may also serve to forestall an eventual holding by the Patent Office or by a Court that such alternative systems are not part of the invention.

The system of the disclosure may also be usable for other purposes than the one originally contemplated. For example, a control for an electric drive may have features which can be utilized for controlling electric generators, rectifiers, or non-electric motors. While claims are not granted for uses of an invention, it is possible to obtain valuable claims relating to different forms of the invention adapted for different uses, and to the combinations of the elements of the invention with those of other apparatus involving such uses.

The mode of operation of the system should receive particular attention as it may serve as a foundation on which to build the broadest claims. While the system may be covered by claims listing its elements and stating their interrelations, such claims cannot be relied upon to cover equivalent systems in which the elements may be different or differently connected. Broader claims in which elements are recited in the form of means of some general type for performing a stated function are therefore often desirable. This type of claim covers not only the system illustrated in the application but also a wide range of equivalents.

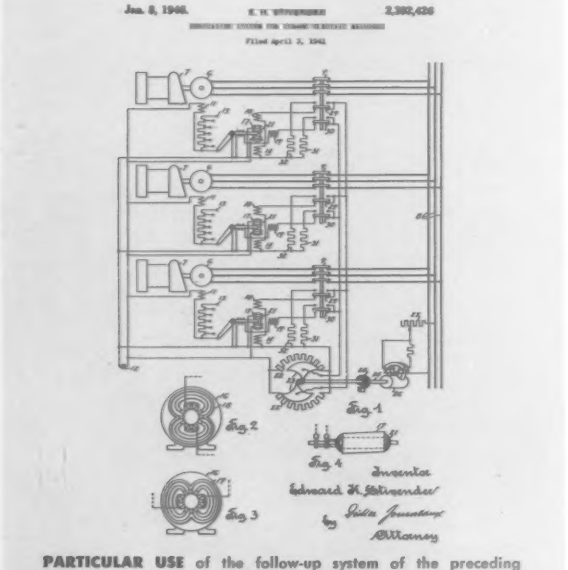
Particularly with electrical systems, it often pays to consider, not only the primary function of the system as a whole, but also the auxiliary functions of the different elements and of the circuits in which they are connected. The disclosure and a prior publication may show systems for performing the same primary function. Elements of the disclosure may, however, perform auxiliary functions not performed in the reference, such as limiting a voltage or forcing a division of current between parallel circuits. Of course, the auxiliary functions of all the elements of the reference should be known. This is not always easy, as such functions are often described incompletely or not at all in patents relating to electrical systems.

In some instances, the intended operation of the system is obtained by giving critical dimensions to some elements. For example, electrical systems may perform quite differently depending upon whether or not magnetic elements are so dimensioned as to operate within the range of so-called saturation.

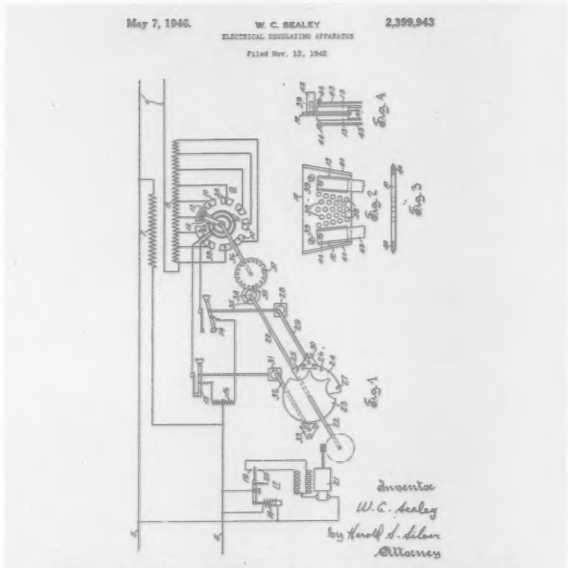
The different steps involved in the operation of some electrical control systems are performed manually. In automatic systems also, the different steps may often conceivably be performed by hand, or at least by means other than those of the disclosure or their equivalents. The operation itself may then be the subject of method claims.

Some regulating systems serve to maintain a chosen quantity, as a voltage, at a predetermined value. All regulating functions are necessarily affected by inaccuracies, and while such inaccuracies may not detract from the usefulness of the system, they may make it difficult to rely on the function as a novel feature. It may then be advantageous to consider the novel combinations of elements of the system, and their auxiliary functions, as generally affecting the regulated quantity without necessarily maintaining it at any particular value.

When the disclosure has been considered from all those angles, any new feature that it may contain should have become pretty well apparent. Features, such as apparatus and its method of operation, may be interdependent, or at least so closely related that they may be considered to constitute a single invention. They may then be claimed in a single patent application. Otherwise, it may be advisable to claim them in separate applications.



PARTICULAR USE of the follow-up system of the preceding figure is the basis for claims to the combinations of regulating elements covered by Patent 2,392,426. Also included in the claims are elements of the follow-up system.



DISCLOSURE AND CLAIMS relating to a tap changing transformer including a tap switch having contacts provided with lubricating inserts are included in Patent 2,399,943. The switch structure is claimed in another patent.

Looking ahead

When an invention becomes published in a patent, it is open to study by the people most able to detect and remedy its shortcomings, and to use it as a starting point for further improvements. It is therefore advisable, while the disclosure is undergoing analysis, to look somewhat beyond its immediate purpose. The inventor may then advantageously be led to think of the most obvious or immediate improvements which would eventually occur to others or to himself in the future development of his invention.

For example, the system may be able to function smoothly once it has been started, but, like internal combustion engines, it may require special means to get it going. For that matter, there may even be problems to be solved to get it to stop. Regulation for imparting a desired operating characteristic to the system may require other means than those previously used in other systems. Likewise, protection of the system against disturbances may call for the development of new and patentable arrangements.

All this sounds like a tremendous program, but of course, it may be gone over lightly whenever it appears that a thorough investigation would be unprofitable. The main thing to bear in mind is that an invention may not reveal all its aspects until it has been scrutinized from a number of different points of view. By a systematic analysis of his invention, the inventor may thus bring out all its features, just as he may make inventions by a systematic analysis of what others have done. A good time to do that is when getting ready to file a patent application. If the inventor does not do it then, somebody else will do it later.

"ONE FOR THE BOOKS"

Preparing Machine Bases for Grouting

LEON A. WATTS
General Superintendent
Service and Erection Department
Allis-Chalmers Mfg. Co.

GROUTING, the process of firmly securing equipment to its concrete base, has been a standard practice of erecting engineers since the early days of the industrial revolution. Although vital to the operational efficiency of equipment, it is nothing more than mere continuation of the main foundation. Grouting does not only lessen machine vibration but provides a sound mooring for equipment which prevents it from shaking loose from the foundation during operation.

Because it seems to be such a basically simple requirement of proper machine installation, some of the preparations that have to be made during the grouting process may, on first sight, appear to be too trivial for careful consideration. Past experiences reveal that each of the steps, no matter how unimportant it may seem, cannot be overlooked if a serviceable and solid foundation is to be laid. Even minor deviations from, and omissions of, any of the steps contained in the ensuing paragraphs may cause the foundation to buckle under the strain, and impose unnecessary outlays of money and time to correct a mistake which should not have been made in the first place.

Preparation of foundations

Before grouting operations are started, an erection engineer should make certain that concrete foundations are thoroughly cleaned and wet. Foundation surface should be chipped with a pneumatic chipping hammer, using either bull point or spade point chisels. If no air tools are available, resurfacing can be accomplished with a hand bush hammer. Although it is not necessary to remove a great amount of the surface, care should be taken to remove all inert and foreign material, as well as all glazed or finished surfaces.

Foundations that are less than 28 days old should be kept wet for at least 12 hours before grouting is poured; foundations more than 28 days old should be kept wet at least 24 hours before grouting is begun. It is vitally important that foundation surfaces be thoroughly saturated in order to prevent water being absorbed from the grout and to assure a good bond between the concrete and the grout. All excess water, however, should be removed from the surface of the original concrete before grouting.

In the event that oil or grease appear on the foundation, the surface should be treated with a caustic or some other neutralizer until all evidence of oil or grease has been removed. Another practical solution would be to remove all oil soaked areas by chipping them sufficiently deep so that no oil or grease would come in contact with the grout. These steps are absolutely essential since no bond can be obtained between the grout and the foundation if there are any evidences of oil or grease. This procedure should be used on all horizontal surfaces up to 45 degrees. Vertical and sloping surfaces steeper than 45 degrees should be washed free of dirt, oil, and grease. If chipping must be resorted to, these surfaces should remain as smooth as possible to prevent grout from spalling and leaving a loose, shattered area between the original concrete and the grout.

Preparing machine bases

Machine bases and sole plates should be thoroughly cleaned of roll scale, rust, paint, oil, or grease before they are set in final position. Where sole plates are used, and it is necessary to slide the machine on sole plates for final alignment after the grouting is completed, it may be necessary to use a lubricant between the sole plate and machine base. Oil or grease should not be used as the weight of the unit will squeeze out the excess and cause it to run down over the surface to the grout, thus preventing the grout from bonding to the metal. Either a light coat of paraffin or a small amount of flake graphite are recommended for this type of lubrication.

All metal surfaces or areas that come in contact with the grout should be wet immediately before grouting is started. This helps to prevent the absorption of water from the grout and acts as a lubricant to facilitate the flow of grout around and under the various foundation bolts and machine parts.

All forms built around the machine bases or sole plates should be made of lumber not less than 1½ inches thick and securely braced against bending or slipping while sustaining the load of the liquid grout. The top of the forms should not be less than six inches above the bottom of the sole plate or machine base so as to assure a head pressure on the grout during the setting process. A coating of paraffin or flake graphite may be applied to that portion of the machine or equipment which will be submerged in the surplus grout. This coating is applied solely to prevent grout from adhering to the side walls of the equipment. Because of this simple precautionary step, the surplus grout can be easily and economically removed after removing the forms.

Stressing these preliminary preparations may seem superfluous because they are so basic to grouting that they cannot be divorced from it. It is expressly for this reason that erecting engineers should insist upon careful and thorough preparation of bases before actual grouting work is begun.

Part II of this article, which will appear in the Fourth Quarter issue of the REVIEW, will deal with grout mixtures and actual placing of grout.

Should Distribution Transformer Ratings Be Revised?

J. B. HODTUM
Central Station Engineer
Allis-Chalmers Mfg. Co., Pittsburgh, Pa.

Reducing standard ratings by five would not impair handling of today's kwhr loads, author states.

AT the present time the standard kva ratings of distribution transformers in the 7,620-volt class and below include sixteen ratings from 1.5 to 500 kva inclusive. It was considered that possibly some of these ratings could be eliminated tending toward reducing the number of transformers both the manufacturer and the user would have to carry in stock in their warehouses.

If we assume that a reduction in the number of sizes is a desirable step we can, by analyzing present ratings, find which ones are the least necessary, and what the effect on the distribution economics would be as a result of their elimination.

Standardization assumes that an ideal range of sizes would follow a series of preferred numbers* with each rating a given percentage larger than the preceding one. Of course, it must be borne in mind, in any proposed change, that practical problems and present practice in the industry often outweigh all other considerations.

Proposed rating changes

Assuming that all transformers up to the 100 kva rating, inclusive, are capable of delivering 150 percent of their rating for a daily peak, then the next larger size of unit should be more than 1.5 times the lower rating. If the ratio is made exactly 1.5, then when the load on the lower rating increases to 150 percent of its rating and is transferred to the next larger rating, the larger transformer would immediately start at 100 percent of its rating. Its load growth could then only be from 100 percent rating to 150 percent rating. If the percent increase in load per year is high, the time required to increase from 100 percent to 150 percent rating would be quite short with frequent changing of transformers in service, resulting in high operating costs.

Figure 1 shows clearly the comparison of today's ratings with a proposed change which eliminates five sizes — the 1.5, 7.5, 37.5, 75, and 200 kva sizes. This change would reduce the number of sizes from 16 to 11, a reduction of 31 percent. Without disturbing all of the present standard ratings it looks like the elimination of the above five mentioned sizes may introduce a worthy compromise without sacrificing flexibility.

If we follow the present standard ratings in our example, the 7.5 kva transformer is permitted to carry 150 percent load before being taken down and replaced with the next larger size, in this case a 10 kva unit. In this case the starting peak load is already 1.5 × 7.5 kva or 11.25 kva, 112.5 percent of the new unit's rating. The 10 kva then could only remain in service for an increase in load from 112.5 percent to 150 percent. This same condition exists for a change from a 37.5 to a 50 kva unit and from the 75 kva unit to the 100 kva unit, and to a lesser degree in some of the larger sizes.

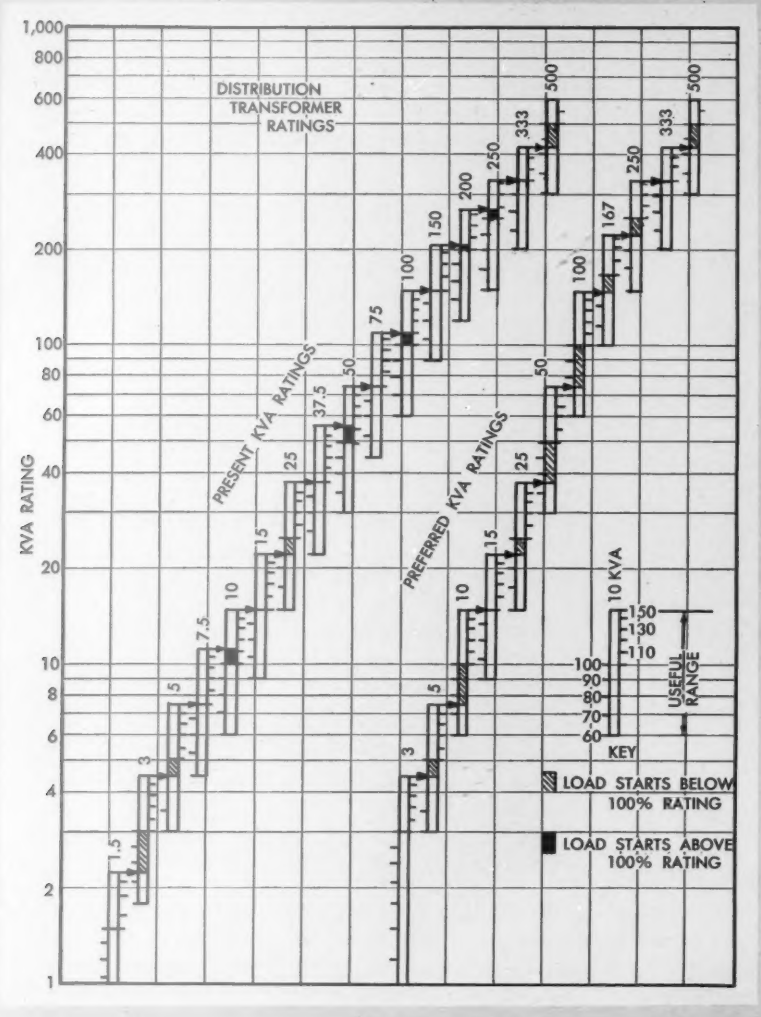
Larger transformers favored

With the preferred kva ratings shown in Figure 1, the load, when transferred from a smaller to a larger transformer, always loads the larger unit below its rating except in the case of the change from the 10 to the 15 kva and from the 250 to the 333 kva.

The 1.5 kva unit is somewhat special and its elimination is considered for several reasons. Surveys among utilities have shown that in almost all areas the load growth with customers served with 1.5 kva units has been very rapid and all present trends point to the continuation of this condition. For example, the addition of one 1,000 watt electric iron to the assumed 1,000 watt load already present immediately overloads the transformer to 133.3 percent of its rating, without considering any other load it may be carrying.

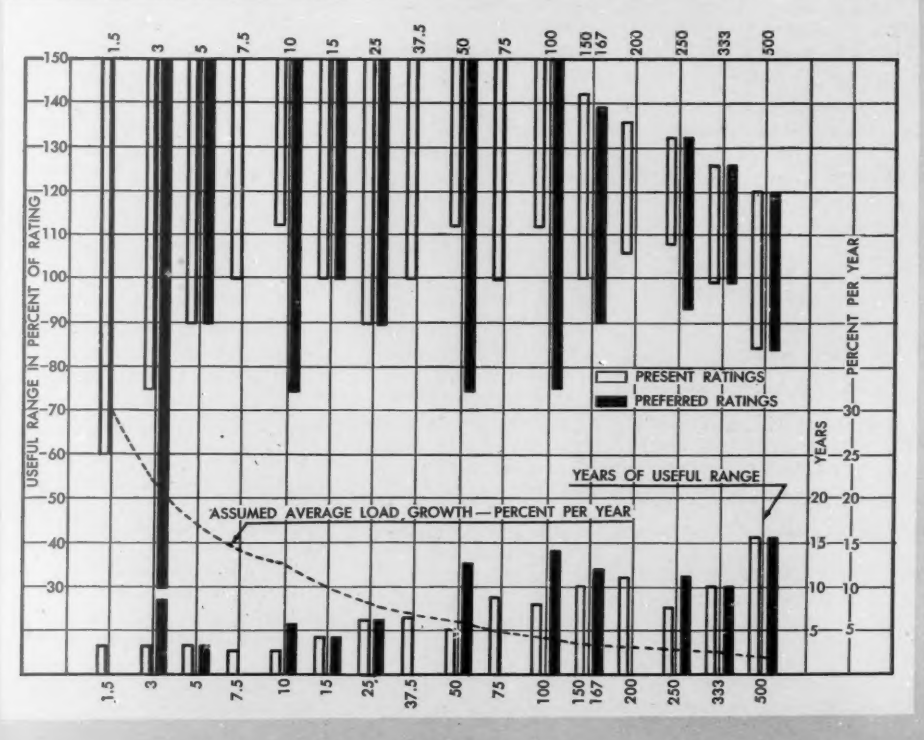
It has been found that the percentage of failures of smaller

* An article on this subject appeared in the First Quarter, 1946, Electrical Review.



WITH PREFERRED RATINGS, only one size of transformer begins at a load above its rating (333 kva). Unsafe overload maximum is considered 150% of rating up to the 100 kva size, decreasing logarithmically to 120% at 500 kva. **(FIGURE 1)**

USEFUL RANGE in years of service and in percent of rating are shown below. Preferred ratings would reduce too frequent transformer changing. Load growth rate is based on best available figures. **(FIG. 2)**



New Products

New Distribution Transformers Feature Weight, Size Reductions

Offering savings in weight of 17 to 46 percent, with corresponding reduction in size, the improved line of standardized distribution transformers meets industry demands for smaller, lighter and more compactly designed units in the 1½ to 100 kva, 2,400 through 15,000 volt classes.

Operational features include flat-slotted terminal lugs on the internal low-voltage leads enabling quick changes from series to parallel or vice versa and the use of oriented electrical core steel for minimum weight. Another feature is the reduction of copper-to-oil temperature gradients to a minimum for better overload characteristics.

Built according to joint EEI-NEMA standardization recommendations, the lightweight units are housed in machine welded, leak-proof tanks of copper bearing steel. The tanks are spray bonderized prior to application of three coats of paint, each of which is baked on separately for added protection against adverse atmospheric conditions. Recessed tank bottoms provide added protection against rust and mechanical damage in handling.

New Single Bus Switchgear Feature Simplicity, Greater Safety

The recently developed single bus, low voltage, metal enclosed switchgear reduces the number of main buses from three to one and eliminates multiple bus transition units. Simplified design and construction make it possible to connect two-high and three-high circuit breakers in adjacent compartments without the use of a transition unit. The reduced number of supports and amount of copper used have resulted in a reduction of live surfaces affording greater safety to operating personnel with easier accessibility of parts.

Standardized parts and sub-assemblies fit both indoor and outdoor units. An optional feature of the outdoor type provides for closing of the breaker panel and the outside front door with the circuit breaker in either operating or disconnected position. This feature is important in outdoor switchgear where it is frequently desired to leave the breaker in the disconnected position in order to provide circuit clearance with the compartment door closed to protect the interior against the weather.

MORE FACTS about these new products are available on request. Write the Allis-Chalmers ELECTRICAL REVIEW, Allis-Chalmers, Milwaukee 1, Wisconsin.

transformers is higher than for the larger ones, probably a result of higher frequency of overloads due to unforeseen load growth among smaller units. The elimination of smaller units should tend to improve the operating record.

Changes are logical

Almost all utilities devote some part of their expenditures to selling the greater use of electricity to small farm or urban users. When, at the same time, we consider that if this sales effort meets with any practical success, the 1.5 kva transformer installation must be changed immediately, does it not seem logical that the larger size unit should have been installed in the first place?

The present kwh consumption per domestic customer has climbed to approximately 1,300 kwh per year. If we accept the proposed goal calling for an eventual average consumption of 10,000 kwh per year, then too frequent changing of transformers in service will be necessary. With industry-wide acceptance of preferred ratings, the necessary changes will be considerably less frequent, resulting in lower operating costs.

Figure 2 shows graphically the loads, both starting peak and maximum peak, that would be carried by each rating for the present ratings and for these proposed ratings. This clearly shows that in the case of 10 kva, 50 kva, 100 kva, and the 250 kva sizes, changes from small ratings to larger ratings start the larger rating at an overload. In the case of the preferred ratings, no transformer when changed from a lower to a higher rating starts at load above its rating.

At the bottom of the diagram vertical dash lines indicate the estimate of load growth per year for each rating. The bottom set of figures indicate the length of time that a transformer would remain in service before requiring a change to the next larger unit based on the above load growth data.

The curve also considers that there would be a logarithmic decrease in the overload capabilities from the 100 to the 500 kva rating. This would start at 150 percent load for the 100 kva and 120 percent load for the peak of a 500 kva unit.

A step in the right direction

From a study of the curves it appears that the proposed change may have considerable merit. Naturally such merit is only present if it results in real benefits to both the user and the manufacturer. Other proposed revisions of the standard ratings have been made and each probably has certain advantages. However, the series proposed does not add any new sizes, it does not eliminate any of the very popular sizes and it provides a very workable solution to the problem of reducing the number of transformers that must be tied up in warehouses throughout the country.

No attempt has been made here to analyze the economics of the new excitation losses or increased investment charges resulting from the use of larger transformers in some sizes, since a complete treatment would be lengthy and would vary widely with different operating companies. However, analyses which have been made show comparisons quite favorable to a reduction in the number of sizes.

These comments are presented to stimulate further discussion with the hope that a better series of preferred sizes will eventually be determined which will be of benefit to both the user and the manufacturer.

Protect Your Motors from *Invasion!*

PART FOUR OF FIVE PARTS*

G. BYBERG and C. D. LAWTON
Motor-Generator Section
Allis-Chalmers Mfg. Co.

Authors discuss application of air-coolers for ventilating various types of enclosed motors and generators.

THE use of air-coolers in closed recirculating systems for individual machines originated with, and, for a long time, was confined to larger high-speed, turbo-type synchronous generators operating at speeds of 1,500 to 3,600 rpm.

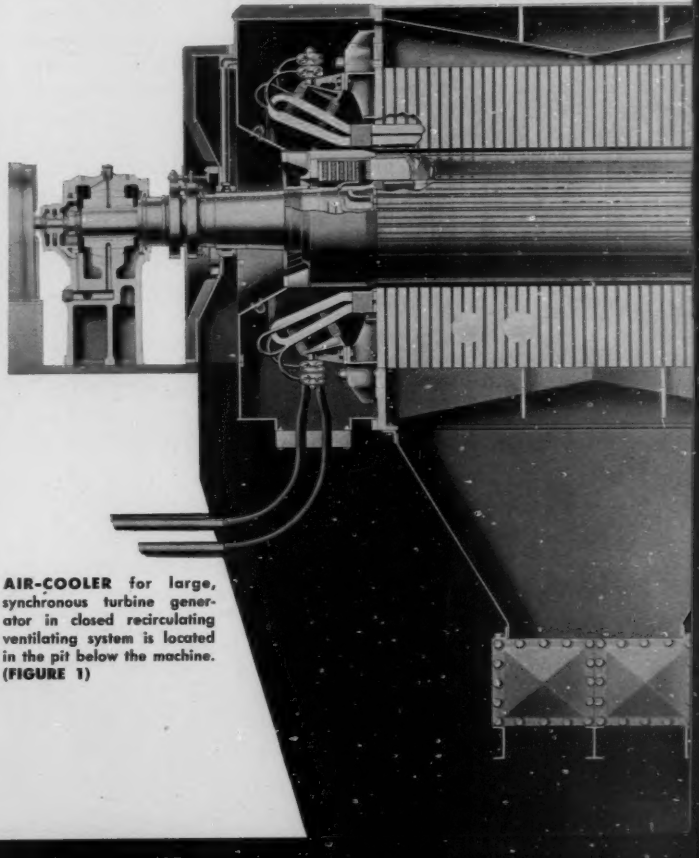
Enclosed machines with air-coolers

At its inception, and during the early days of its development, the steam turbine-driven synchronous generator was of the salient-pole type, either geared or directly connected to turbines operating at much lower than present day speeds. The advent of the high-speed cylindrical rotor type turbo-generator, with its deep radial and long axial core section and inherent high field temperatures, made it necessary to enclose the machine in order to obtain an adequate method of cooling. Ductwork and damper systems were used originally. These drew the cooling air from the room or from the outside and discharged it into the room, or outside. This, however, became too cumbersome and wasteful of space as machine sizes increased and, together with the prevailing ambient temperatures, forced the eventual use of air-coolers.

Application of air-coolers next spread to medium and large sized synchronous condensers and, in later years, to hydraulic turbine-driven synchronous generators of larger sizes, as well as to other types.

In other types of large, high-speed machines, such as salient-pole synchronous generators or motors, direct current generators or motors and induction motors, the only physical limitation restricting the use of air-coolers in a closed system is whether the peripheral speed is high enough so that the rotor fans can be designed to provide the air pressure necessary to overcome the pressure drop through the cooler and duct system. For that reason, as well as the fact that bracket bearing construction, standard in the smaller sizes, frequently requires too much change to make them adaptable, the use of this system for small machines is usually impractical. Furthermore, it should not be construed that because a machine can be so arranged it is always economically justifiable. As a matter of fact, where small machines are required to be enclosed, the totally enclosed fan-cooled type may, in some cases, be a better answer to the problem.

Cleanliness — The life of a machine is dependent upon its insulation and is, therefore, enhanced by the extent to which it is kept clean and free from injurious elements. In a system of this kind, if the ductwork is well made and the enclosures are properly fitted and tightened, practically all dust, dirt, fumes, excess moisture, oil-vapors, etc., are kept out of the machine. Hence, little time will be lost for cleaning and the machine will operate at uniform temperatures since its passages remain free and unobstructed. Of course,



AIR-COOLER for large, synchronous turbine generator in closed recirculating ventilating system is located in the pit below the machine. **(FIGURE 1)**

* Parts One, Two, and Three of this series appeared in the September, 1944, March, 1945, and March, 1947, issues of the *Electrical Review*.

these advantages may, with equal right, be claimed for a forced-ventilated system in closed circuit with air-coolers and filters.

Circulation of ventilating air — The recirculation of ventilating air by means of fans integral with the machine becomes a point of greater reliability since it is not dependent upon external equipment as is the forced-ventilated system.

It is desirable that the heated air be kept out of the machine room. This is, in many places, important from the standpoint of operating personnel comfort; in the tropics, and sometimes even in more temperate climates, the generator room may otherwise reach temperatures that greatly shorten the life of equipment insulation.

Fire hazards — Since the volume of air in a system of this kind is relatively small, it will not support combustion for any protracted period of time. Also, provision can be made for the introduction of an inert gas, such as CO_2, to smother any incipient fire, a practice deemed impractical in any but a closed system. This is an important consideration for large machines, particularly when located in isolated places as is generally the case with hydro-plants.

Reduction of noise — The subject of noise levels of rotating machines is much too broad and complicated to come within the limited scope of this article. It may, however, be mentioned that the main sources of noise are approximately as follows:

High-Speed Machines (3,600/1,200 rpm) — Largely windage.

Medium Speed (1,000/327 rpm) — Windage and magnetic.

Low Speed (300 to 100 rpm) — Largely magnetic.

Windage noises, being largely air-borne, may best be reduced by the use of an enclosed machine with a recirculating system. Well designed enclosures, baffles and duct system effectively confine windage noise within the ventilating system. Usually this is sufficient to reduce the windage noise appearing outside of the machine to a satisfactory value. In exceptional cases, enclosures may have to be lined with sound-absorbing materials.

Noises from magnetic sources are much harder to control, but this should not be interpreted to mean that they are necessarily objectionable where they are indicated as predominant. Magnetic noises may, for example, be transmitted through foundations and appear objectionably at some remote point. Or, some part of the machine may be resonant with periodic variations of the machine's magnetic forces and result in vibratory noise in such parts. Usually this may be counteracted with some form of mechanical damper; for example, if it's the end enclosures a simple remedy may be cork or rubber gaskets between the covers and yoke, or stiffening the covers by adding or welding to them a rib or series of ribs having their greatest section in the same plane as the direction of the vibration.

Low-speed machines

Through common usage the term low-speed is generally considered synonymous with a low number of revolutions per minute. A clear distinction, however, should be made between this and a machine having a low rotor peripheral velocity. A machine may have a low speed in rpm, but be of such diameter that its fans will circulate the requisite amount of air in a closed system with an air-cooler of proper design. However, a machine of very low rotor peripheral velocity may not be able to ventilate itself as an open machine, even with the use of special fans. Hence, in the case of low peripheral speeds, it will be necessary to use motor-driven booster fans or blowers when the machine is used in a closed system with an air-cooler. Wherever conditions permit, such blower-units are usually mounted on the frame of the machine. (See Figure 7.)

Cooling water requirements

The amount of cooling water required is a function of the cooling water temperature, the difference between temperature of the water and the air from the cooler and the cooler surface area. The skin resistance to heat transfer of the surface in contact with the air being cooled is generally of much greater influence than the tube thickness. The coolers will usually be designed to deliver air from 90 to 104 degrees F (32 to 40 C), with the quantity of air being such that its rise in passing through the machine does not exceed approximately 15 degrees C.

A close approximation of the amount of cooling water required, with normal cooler design, may be had by multiplying the kw full load loss in the machine by the multipliers shown below for various water temperatures, the result being in gallons per minute:

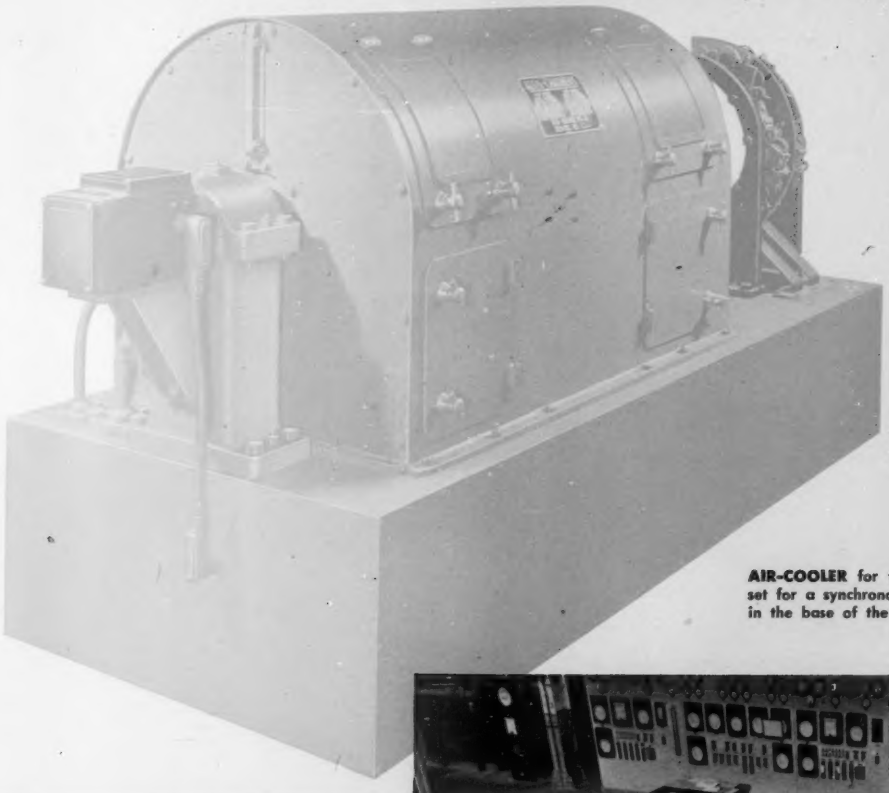
Water Temperatures Degrees F	GPM Multipliers
70	0.7
75	0.8
80	0.9
85	1.0
90	1.1
95	1.2

The majority of installations, with the exception of central stations, will use raw water and standard practice is to design air-cooler header and tubes for about 25 pounds working pressure. Special designs can, of course, be obtained for higher pressures.

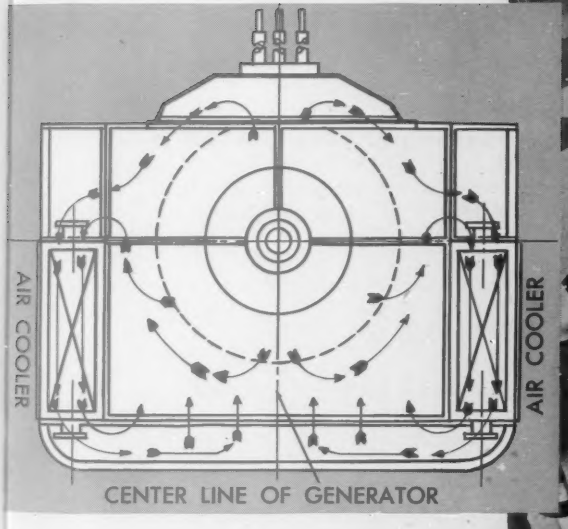
In steam central stations, several alternate means are possible. The air-cooler may be in parallel with the condenser circulating water system, which usually means a larger cooler with fewer passes in order that the pressure drop or head loss through the cooler be maintained approximately the same as through the condenser.

Turbine condensate is also used sometimes as a cooling medium, where its temperature is sufficiently low and the quantity available is sufficient to affect the required cooling. Obviously this is impractical where the difference between condensate and cooling air temperature is less than about 10 degrees F, unless auxiliary means are provided to lower the condensate temperature. In some cases it may be found practicable to install an auxiliary raw-water air-cooler section in series with the condensate operated section in order to complete the cooling. In any case, it will be obvious that the heat energy of the generator losses may be reclaimed in the cooling medium and returned to the boiler feed makeup.

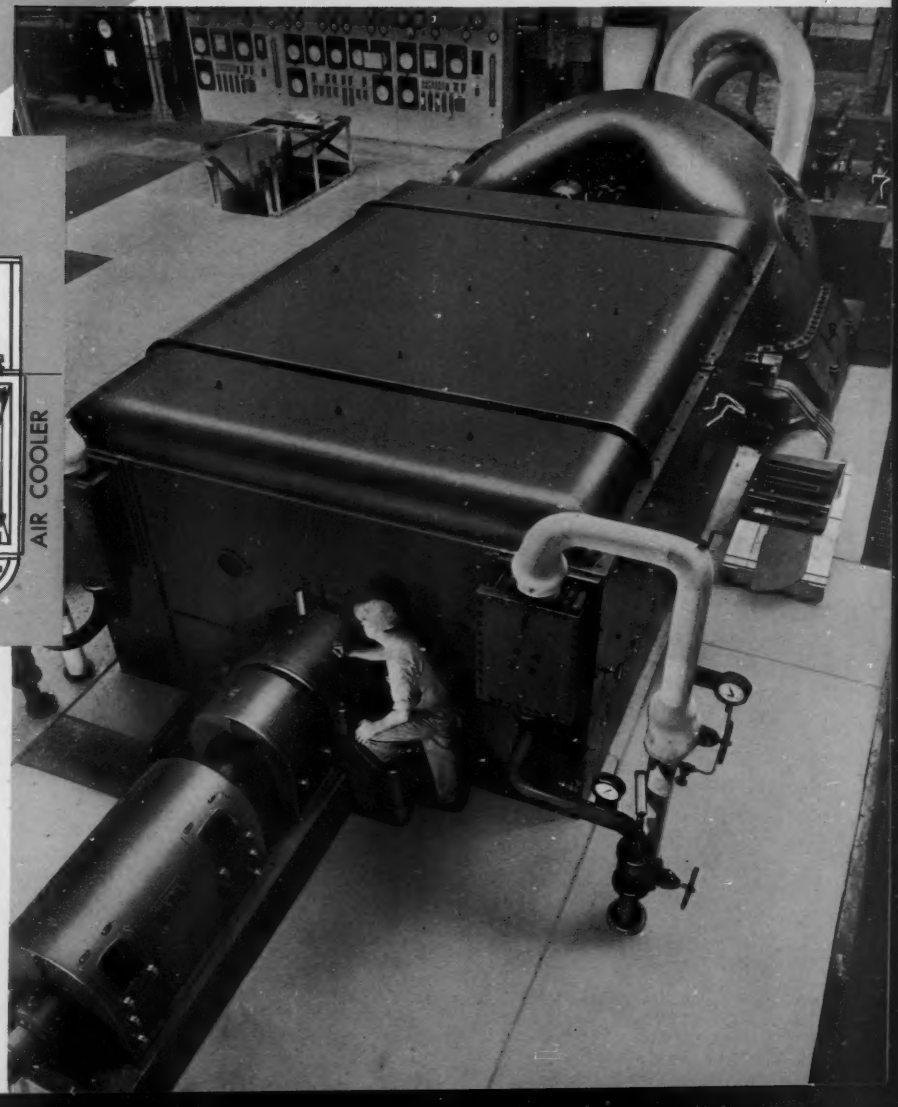
Installations may have to be made in locations where water is either very scarce or else contains so much silt as to clog the tubes very quickly. In such cases it may be necessary



AIR-COOLER for this large main and pilot exciter set for a synchronous turbine generator is contained in the base of the unit. **(FIGURE 2)**

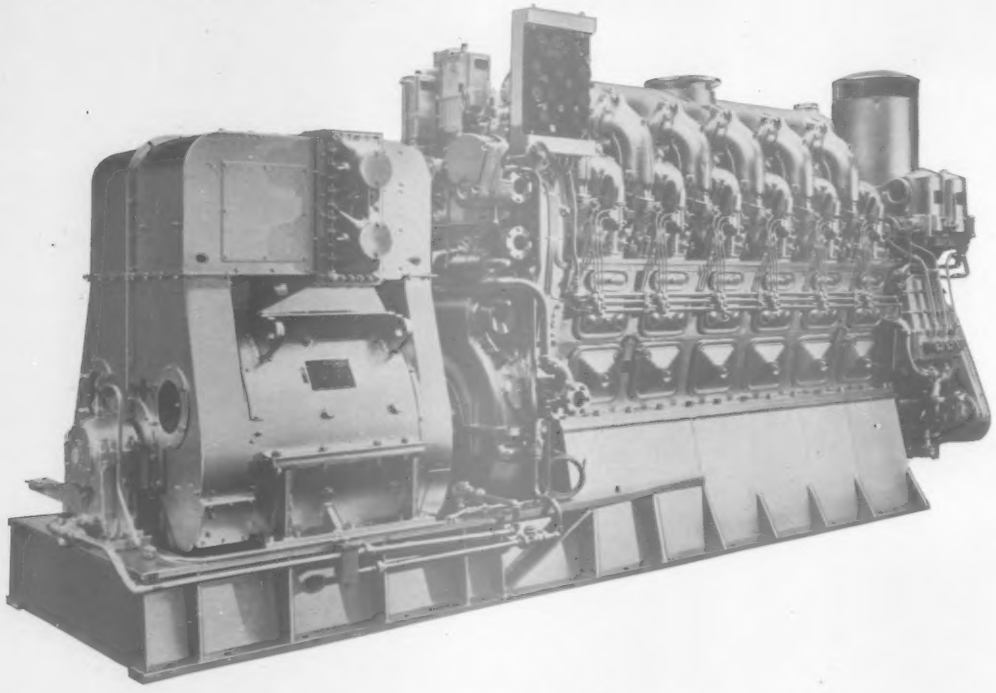


SCHEMATIC END-VIEW of ventilating diagram for a synchronous machine with air-coolers mounted on the sides. **(FIGURE 3)**



AIR-COOLERS for this 20,000 kw, 3,600 rpm condensing, impulse reaction, steam turbine generating unit are side-mounted in the housing of the synchronous generator. **(FIGURE 4)**

TYPICAL TOP-MOUNTED air-cooler arrangement on a diesel engine driven d-c generator for marine propulsion service. **(FIGURE 5)**



to bring in a supply of clean water to be used for continuous recirculation through the coolers and external heat radiators.

Where the cooling medium is salt water, as in marine service, or water containing other corrosive agents, it is generally advisable to resort to the use of air coolers having non-ferrous headers and tubes.

Location and arrangement of coolers

The location of the air-cooler is, in certain cases, definitely fixed by the type of machine to which it is applied. In others, it is subject to variations to suit the purchaser's requirements. There are three possible locations for horizontal machines, viz:

1. In the foundation or ductwork below the machine.
2. In housings at side of machine.
3. In enclosures at top of machine.

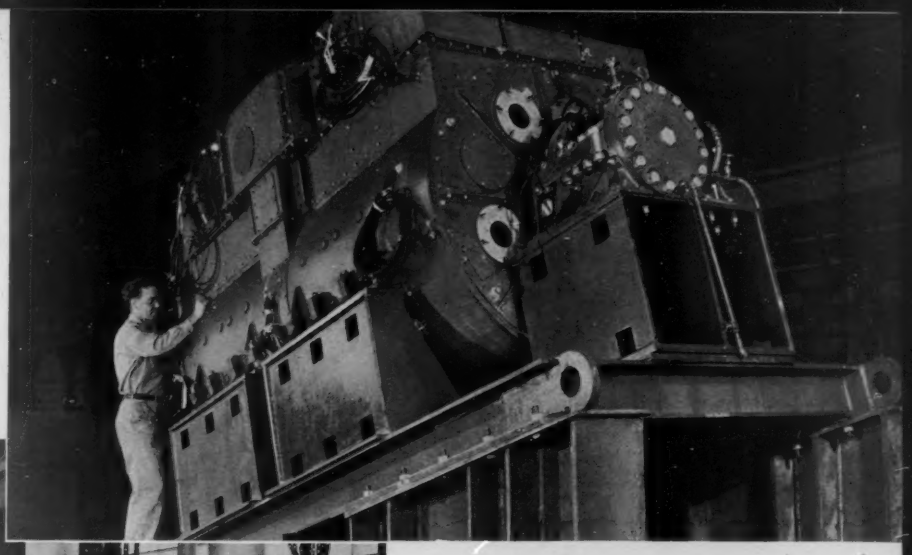
Basically, the first mentioned location may be considered conventional for most a-c machines. A schematic sectional view, as applied to a turbo-type synchronous generator, is shown in Figure 1. The main air-paths are fairly obvious, so that the direction of the air through the internal parts of the machine need not be described in detail. Fans at each end of the rotor draw the air from the pressure chambers formed between the inner and outer end covers forcing the air through the multiple internal paths of the machine and discharge it through the bottom of the stator yoke into the cooler. After being cooled, the air returns into the pressure chambers.

In the case of salient-pole synchronous machines, or induction type machines, the same general scheme may be used. The air is drawn in through the stator end covers and discharged through the bottom of the yoke. The internal paths will be somewhat different than in the turbo-generator since, in these machines, the air usually passes through the rotor and air gaps, then through the stator core ducts and along the circumferential passage formed between the back of the stator core and yoke wall down to the discharge opening in the bottom of the yoke to the cooler.

The somewhat costlier side-mounting arrangement is becoming increasingly popular for larger high-speed horizontal machines and has several advantages. In the case of a central station generator, it is sometimes difficult to find sufficient space below the unit to locate the cooler, because of the presence of the condenser, condensate pumps, air evacuators, etc. Furthermore, the side-mounting avoids a great deal of water piping, valves, etc., at that point. (See Figures 3 and 4.)

In the case of other machines, it may eliminate the need for deep and costly foundations. A large, synchronous condenser, for example, may have only a temporary location subject to change with the shifting of load on the transmission system. In such a case, the side-mounted cooler arrangement would help to reduce the cost of the temporary location foundations.

The slightly higher cost is brought about by the fact that special stator structure and enclosing housings for the air



TOP-MOUNTED AIR-COOLERS and a motor driven circulating blower are used to ventilate this low-speed, double armature direct current propulsion motor. **(FIGURE 7)**

GAS TURBINE-DRIVEN induction generator has air-cooler mounted on top. Turbine is used in conjunction with the Houdry process to burn gases in a petroleum refinery. **(FIGURE 6)**

coolers are required and because coolers for large machines are usually split up in two or more sections, with one-half of the total located on each side of the machine.

The main scheme of ventilation is similar to that for coolers located below the machine and differs only in the relative position of coolers to the machine. The air from the cooler, as before, goes into the pressure chamber between the outer and inner end covers and is forced through the machine ventilating paths, housings and coolers, by the shaft-mounted fans, as indicated in Figure 2. The discharging warm air is split into two paths at the bottom of the stator yoke or frame so that one-half will pass through the cooler sections at each side.

The third, or top-mounting arrangement, is resorted to where, for reasons of space limitations, the other two are not readily applicable. Marine service is typical of the almost exclusive use of this arrangement and, ordinarily, it is the only practicable arrangement for direct current machines. (See Figures 5 and 6.)

With the cooler top-mounted, definite precautions must be taken in order to preclude the possibility of water getting into the machine in case of tube failure. The interleaving of interior baffles and shelves usually provides adequate protection, but it also increases the circuit air pressure drop and may thus adversely affect the rotor fan design. For certain classes of service, such as marine propulsion, it is the general practice to resort to the somewhat costlier double-tube cooler construction, where, in case of failure of an inner or outer tube, the remaining tube will withstand the working water pressure, eliminating the possibility of harmful effects. Where side or bottom mounted coolers are used, a faulty single tube can usually be plugged out of service until such time as repairs can be made.

In the case of vertical a-c machines, the usual arrangement is to mount one or more cooler sections tangentially to the periphery of the stator yoke. (See Figure 8.)

An air housing which completely encloses the machine and coolers must then be used from the floor line and over the top of the machine. The air from the coolers passes into this housing, from where it is drawn into the top and bottom of the machine by the rotor fans. The housing may consist in its entirety of reinforced sheet steel but, in the case of generators of very low speed and having a relatively low overall height, it may be formed by a concrete barrel setting in the foundation, with deck or cover plates set flush with the station floor.

In the case of large, vertical, hydraulic turbine-driven synchronous generators, it is conventional to split up the coolers into anywhere from two to ten or more sections. One reason for this is to keep the air-housing diameter to a minimum. Another reason may be the specified requirement that the machine shall be able to operate at rated load and temperature rise in spite of failure of one of the cooler sections.

Conclusion

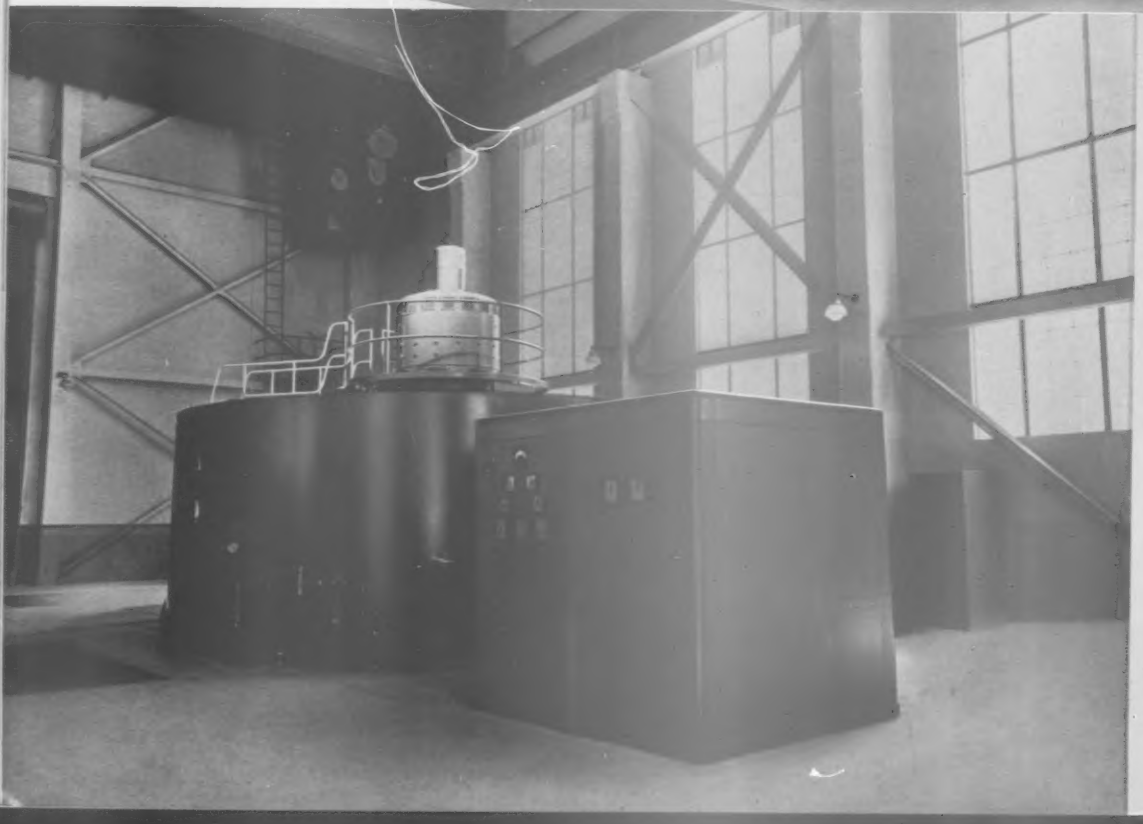
The advantages inherent to the air cooler system of ventilation have already been stated and, by inference, the reasons for its consideration should be equally obvious.

In general, the system finds its practical application for the larger sizes capable of air circulation without the use of external fans or blowers. The ratings to which this is applicable will vary approximately inversely with the square of the speed; for example, if we say that at 600 rpm a 1,000 kva generator is suitable to ventilate itself then at 300 rpm the minimum size would be $1{,}000 \times (600/300)^2$, or 3,000 kva. However, there is no simple way of expressing, or showing graphically, any absolute defining limitations because of the various design factors which may affect the machine frame dimensions.

There may, of course, be cases where the use of machines with separate external ventilating equipment in series with the coolers is perfectly justifiable, as, for example, a low speed motor directly connected to the propeller shaft of a ship.

In the case of high-speed machines, there are seldom any cases, aside from geared turbo-generators, where it is economically justifiable to use the system for ratings below one kva or one hp per rpm.

INSTALLATION VIEW of a vertical high-speed synchronous machine, with air-housing removed, showing the air-cooler arrangement. **(FIGURE 8)**



THIS LARGE synchronous generator has six air-cooler sections equidistantly spaced around the stator periphery inside the air-housing. Unit is driven by a vertical hydraulic turbine. **(FIG. 9)**

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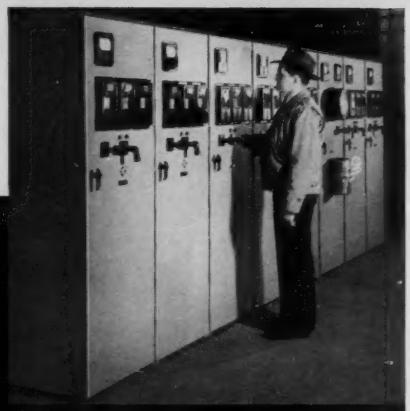

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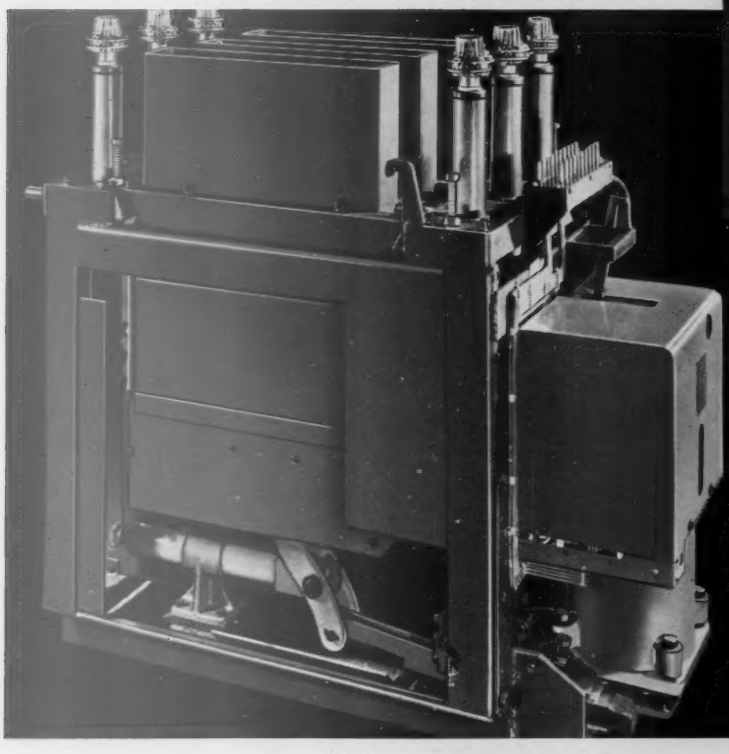

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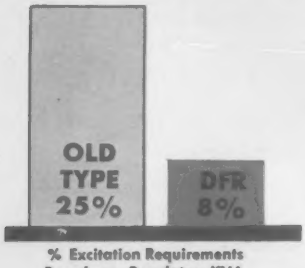

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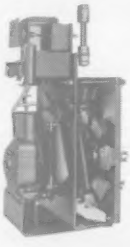

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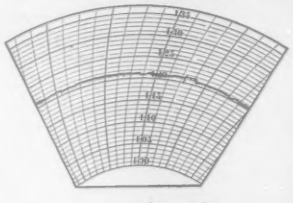

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